# Powertrain Component Modeling

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# POWERTRAIN LIBRARY

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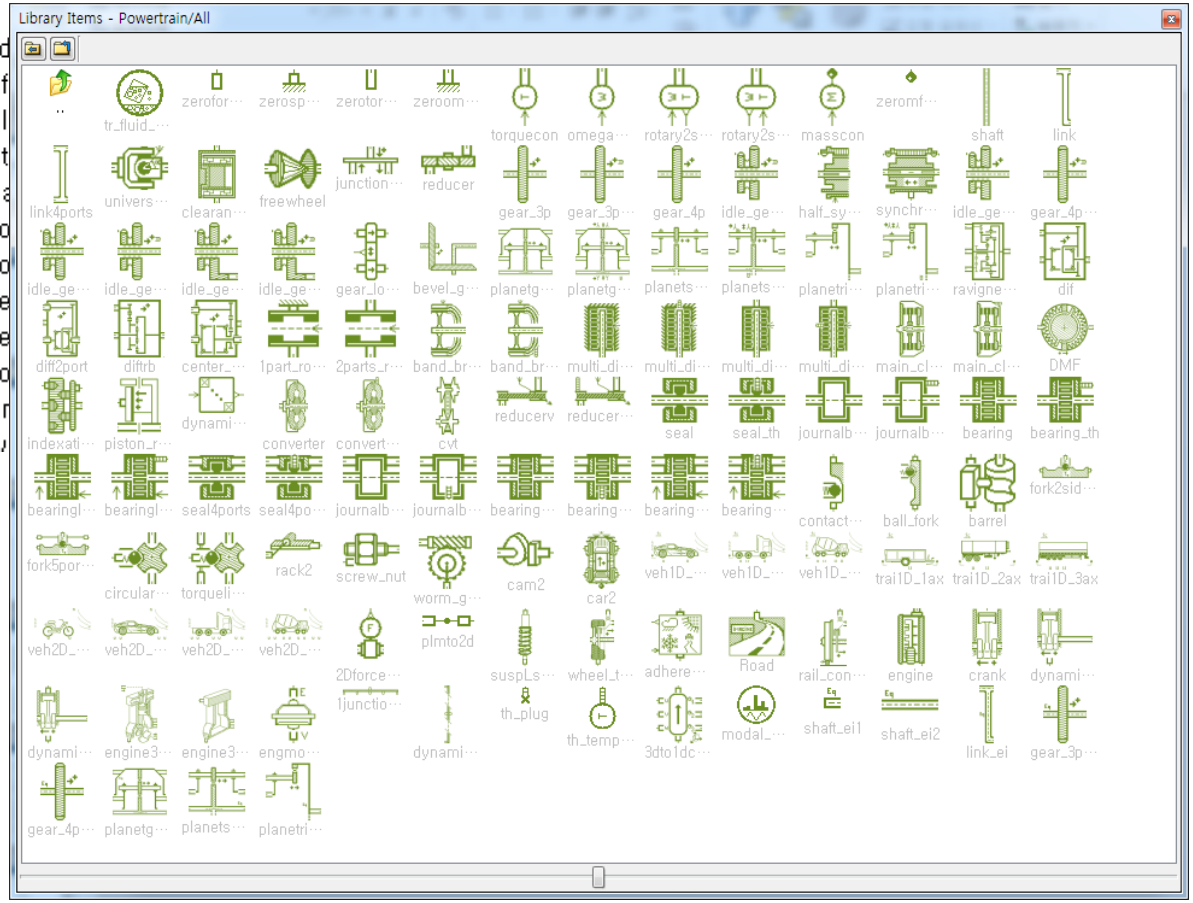
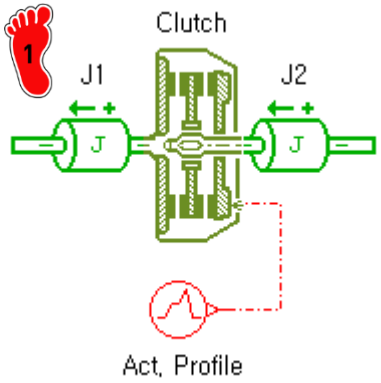
| tr_fluid_data | fluid data |
| All | |
| tr_fluid_data | fluid d |
| zeroforcesource | zero f |
| zerospeedsource | zero l |
| zerotorquesource | zero t |
| zeroomegasource | zero a |
| torquecon | null to |
| omegacon | null to |
| rotary2signal1 | conve |
| rotary2signal2 | conve |
| masscon | null to |
| zeromfsource | zero r |
| shaft | rotary |



# CLUTCH




$$F_{fric} = F_{dyn} \times \tanh\left(2 \times \frac{\omega_{rel}}{d\omega}\right)$$

Parameters of main_clutch [TRMC0D-1]

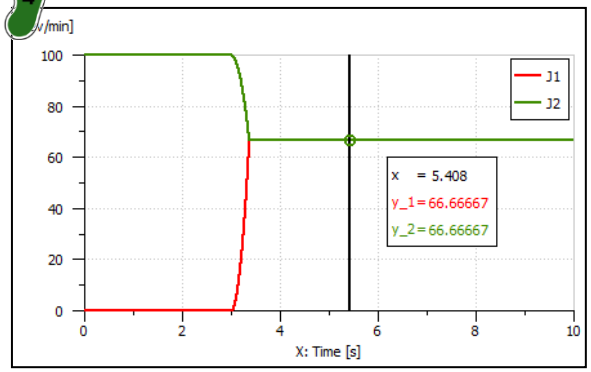
| Title | Value | Unit |
|---|---|---|
| maximum Coulomb friction torque (dynamic) | 100 | Nm |
| rotary stick velocity threshold | 1 | rev/min |

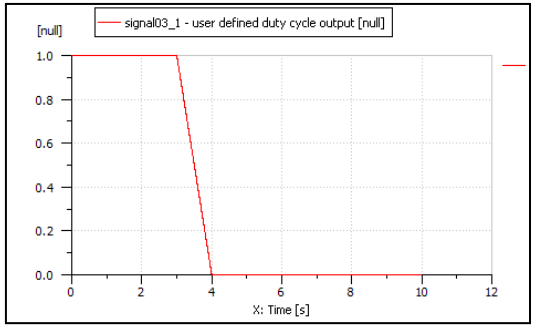
Parameters of signal03 [UD00-1]

| Title | Value | Unit |
|---|---|---|
| number of stages | 3 | |
| cyclic | no | |
| time at which duty cycle starts | 0 | s |
| output at start of stage 1 | 1 | null |
| output at end of stage 1 | 1 | null |
| duration of stage 1 | 3 | s |
| output at start of stage 2 | 1 | null |
| output at end of stage 2 | 0 | null |
| duration of stage 2 | 1 | s |
| output at start of stage 3 | 0 | null |
| output at end of stage 3 | 0 | null |
| duration of stage 3 | 1e+06 | s |

J1 = 1 kgm^2
w_ini = 0

J2 = 2 kgm^2
w_ini = 100 RPM

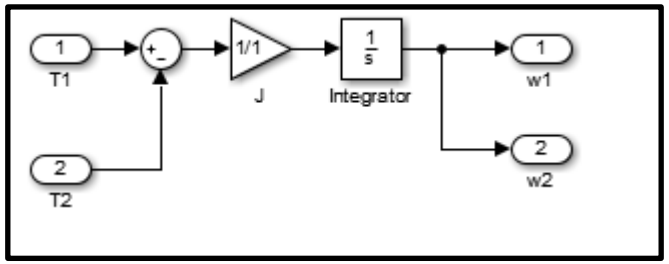


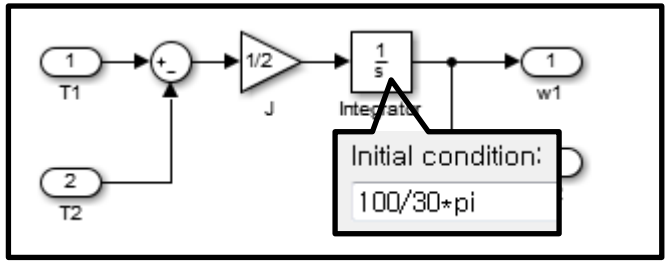

1. 클러치 모델 구성
2. J1, J2 parameter 입력
3. clutch, act. profile parameter 입력
4. Run 및 J1, J2 속도 확인 (Run Parameters에서 Print interval 0.001로 setting)

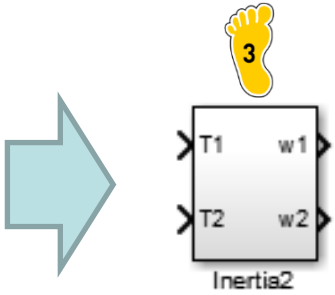
# CLUTCH

1 J1




2 J2




1 J1 inertia 모델 구성

2 J2 inertia 모델 구성 및 초기 속도 입력 (100 RPM)

3 inertia subsystem 구성

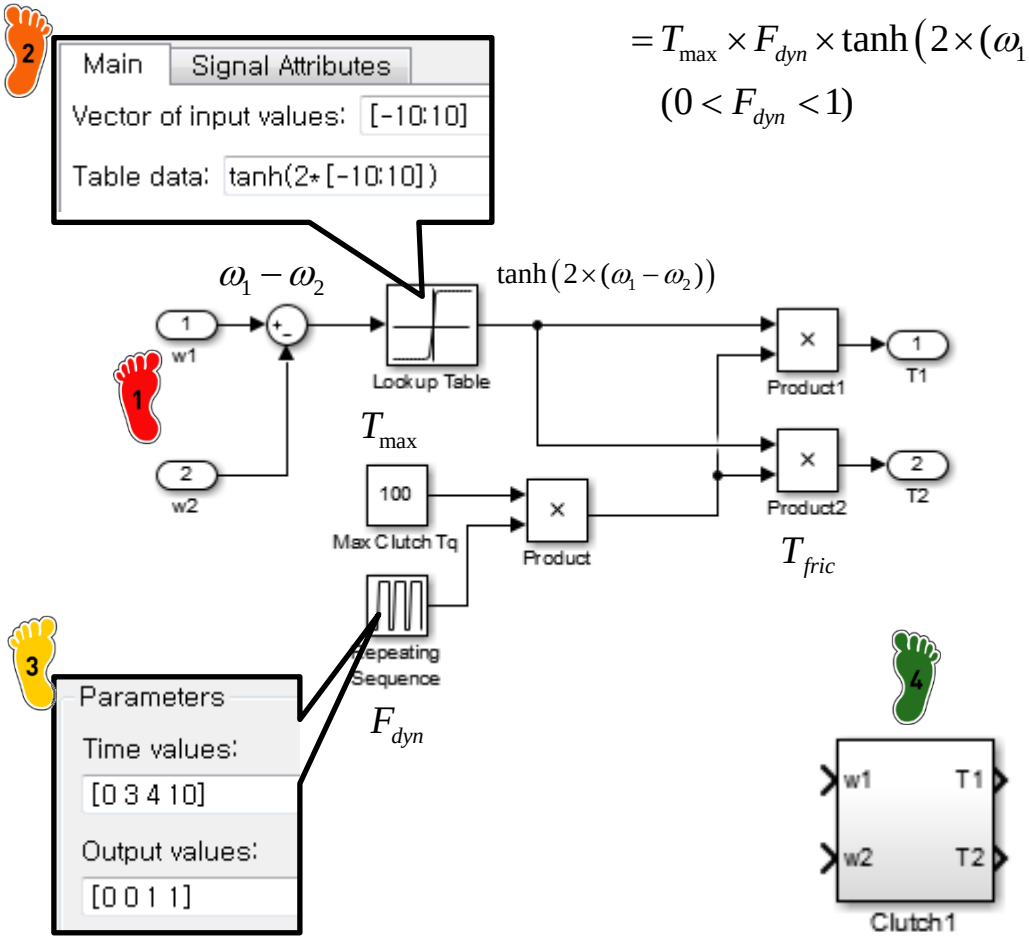
4

# CLUTCH

$$F_{fric} = F_{dyn} \times \tanh\left(2 \times \frac{\omega_{rel}}{d\omega}\right) \Rightarrow F_{fric} = F_{dyn} \times \tanh\left(2 \times (\omega_1 - \omega_2)\right)$$

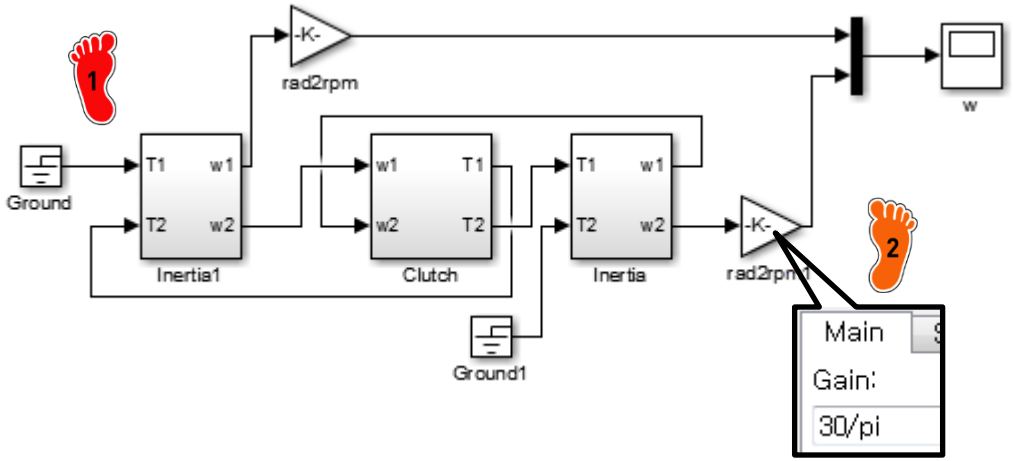
$$T_{fric} = T_{\max} \times F_{fric} = T_{\max} \times F_{dyn} \times \tanh\left(2 \times (\omega_1 - \omega_2)\right)$$

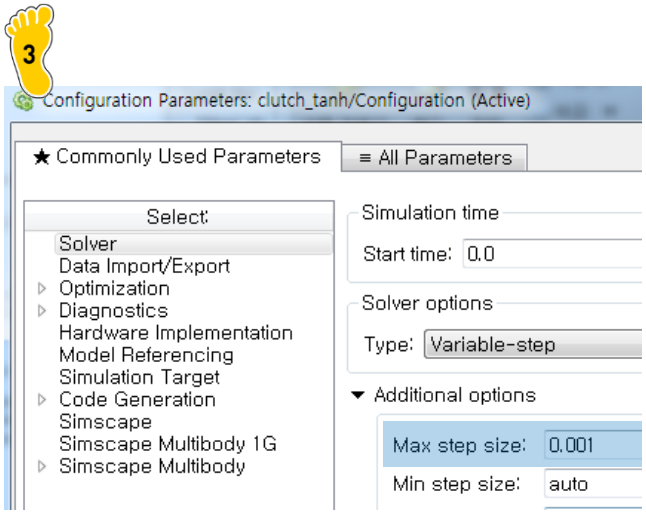
$$(0 < F_{dyn} < 1)$$

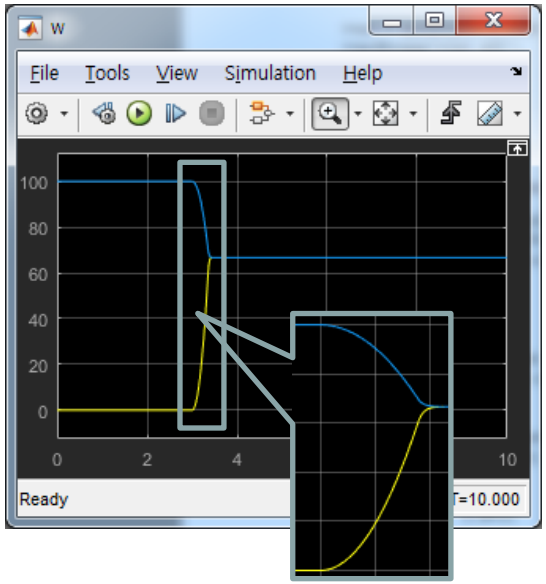



1. 클러치 모델 구성
2. tanh func. table 입력
3. act. profile parameter 입력
4. clutch subsystem 구성

# CLUTCH



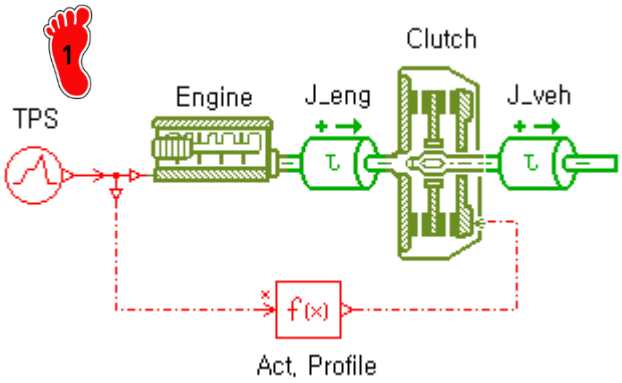

1 전체 system 구성

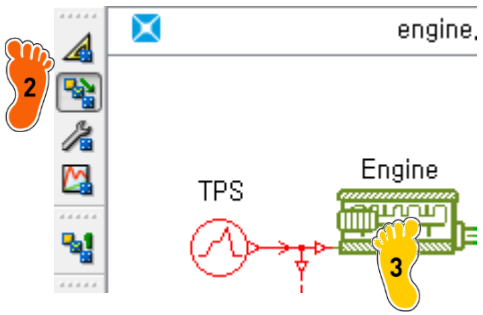
2 rad/s → RPM 변경 parameter 입력

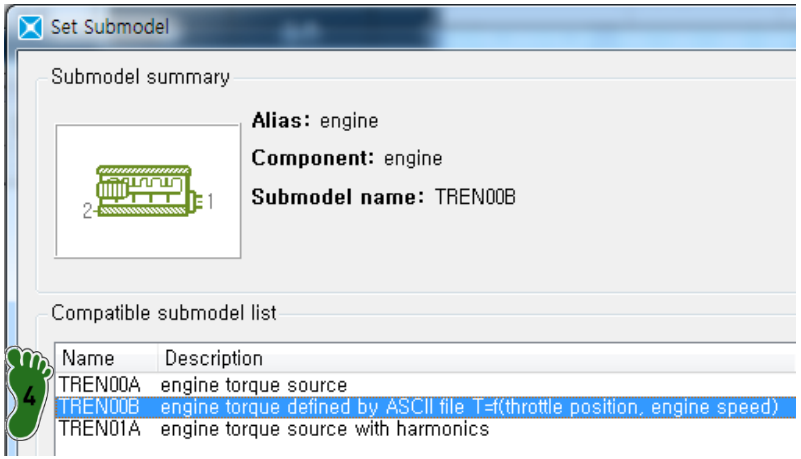
3 Run 및 J1, J2 속도 확인 (Solver Parameters에서 Max step size 0.001로 변경

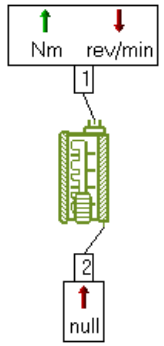
4

# ENGINE



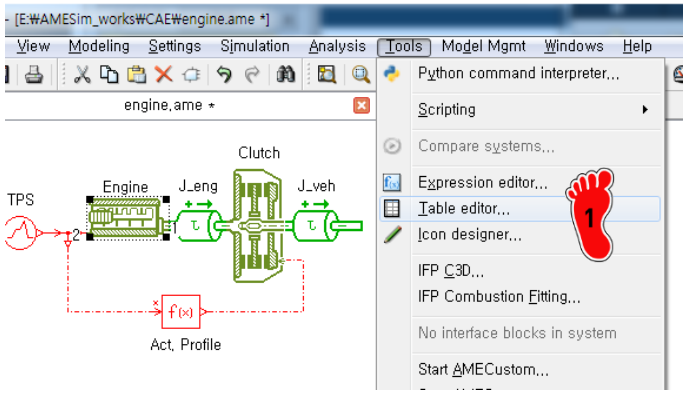



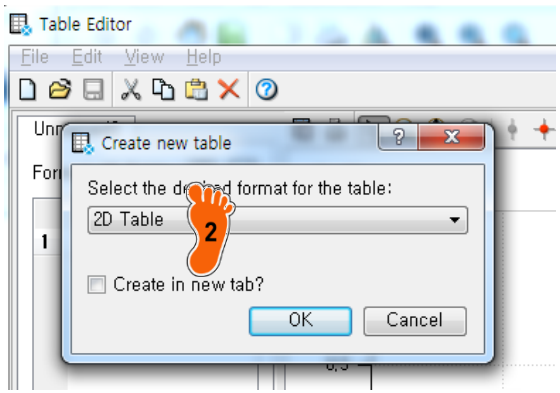



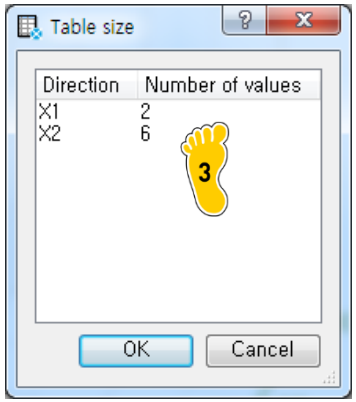

$$T_{eng} = f(TPS, RPM)$$

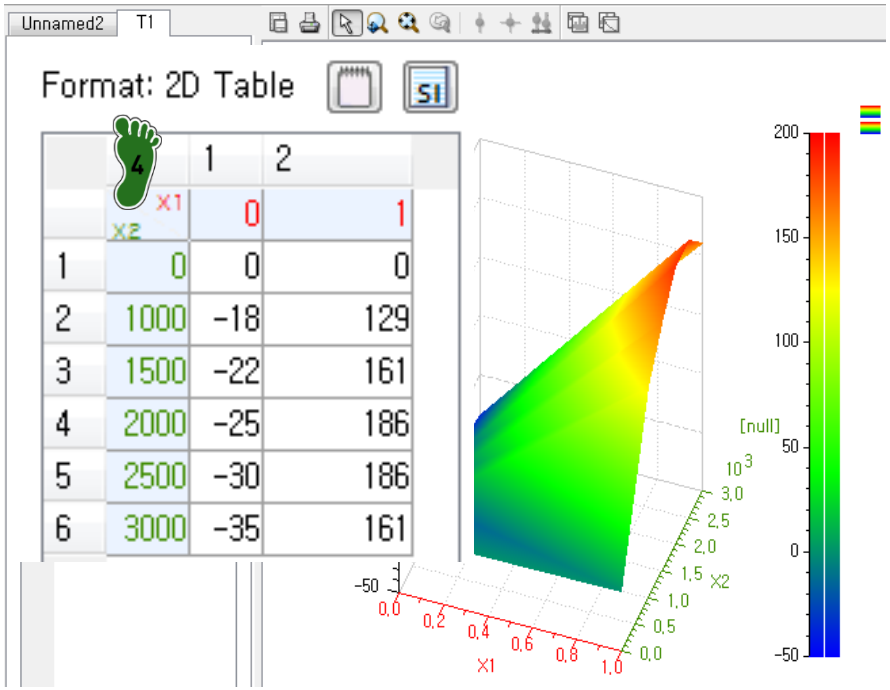
1. 엔진/클러치 모델 구성
2. 왼쪽 toolbox에서 submodel mode 클릭
3. engine모델 더블클릭
4. TREN00B 모델(토크맵 모델) 선택 후 OK 클릭

# ENGINE



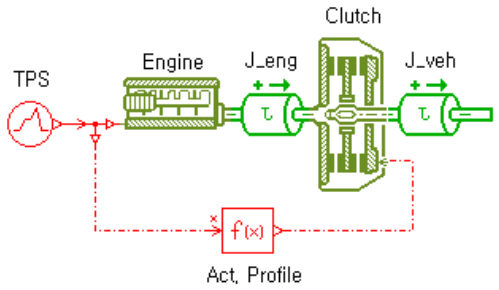




1. Tools → Table editor 클릭
2. File → New 클릭, 2D Table 선택 후 OK
3. X1 : 2, X2 : 6 입력 후 OK
4. 생성된 table에 TPS와 RPM에 따른 torque 값 입력 후 파일 저장

# ENGINE

Parameters of engine [TREN00B-1]

| Title | Value |
|---|---|
| input data out of range | extrapolate |
| discontinuity handling | inactive |
| filename for engine torque [Nm] function of throttle position [0,1] and engine speed [rev/min] | torque.data |




① J_eng = 0.1 kgm^2, w_ini = 0
② J_veh = 50 kgm^2, w_ini = 500 RPM
③ clutch friction torque = 200 Nm

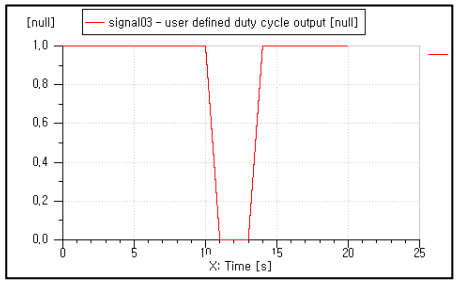
Parameters of signal03 [UD00-1]

| Title | Value | Unit |
|---|---|---|
| number of stages | 5 | |
| cyclic | no | |
| time at which duty cycle starts | 0 | s |
| output at start of stage 1 | 1 | null |
| output at end of stage 1 | 1 | null |
| duration of stage 1 | 10 | s |
| output at start of stage 2 | 1 | null |
| output at end of stage 2 | 0 | null |
| duration of stage 2 | 1 | s |
| output at start of stage 3 | 0 | null |
| output at end of stage 3 | 0 | null |
| duration of stage 3 | 2 | s |
| output at start of stage 4 | 0 | null |
| output at end of stage 4 | 1 | null |
| duration of stage 4 | 1 | s |
| output at start of stage 5 | 1 | null |
| output at end of stage 5 | 1 | null |
| duration of stage 5 | 1e+06 | s |

Parameters of signal03 [UD00-1] | Watch parameters

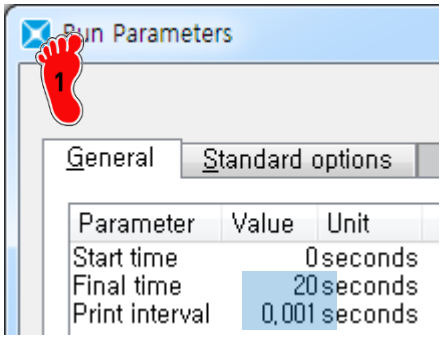

Parameters of fofx [FX00-1]

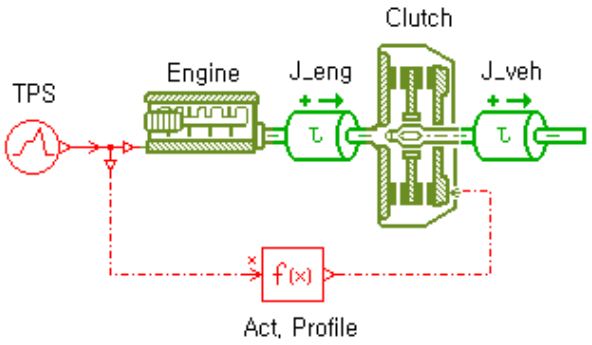
| Title | Value |
|---|---|
| expression in terms of the input x | 1-x |

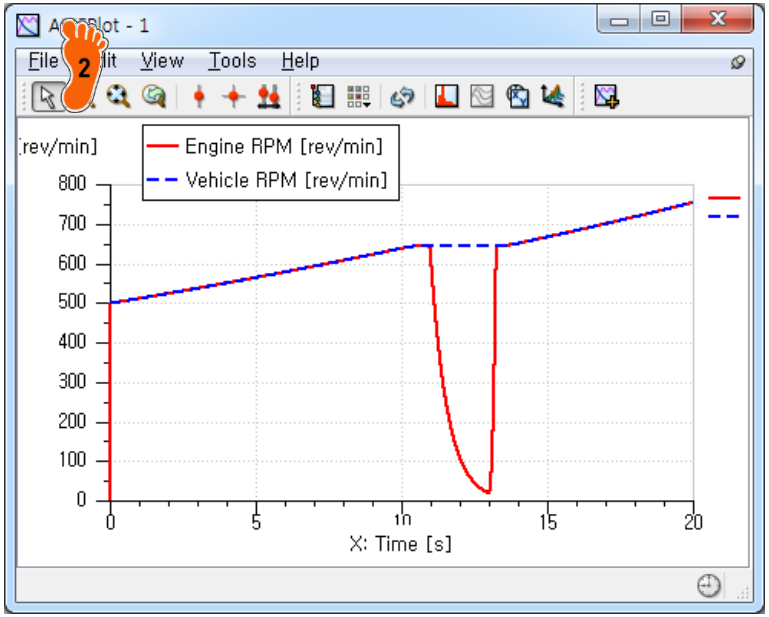



1. simulation mode 변경 후, 엔진 parameter에 torque맵 파일 경로 지정
2. J_eng, J_veh, clutch parameter 값 입력
3. Act. Profile에 function value 수식 입력 (1-x)
4. TPS에 해당 parameter 값 입력

# ENGINE



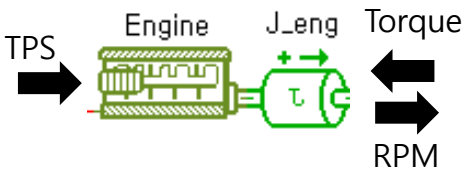

1 Run Parameters에서 Final time, Print interval setting

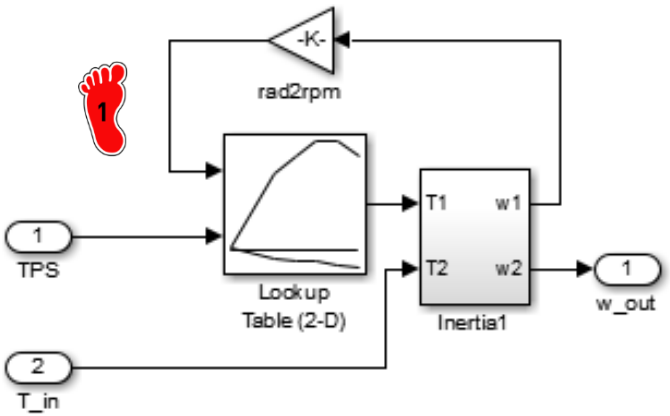
2 Run 및 Engine, Vehicle RPM 확인

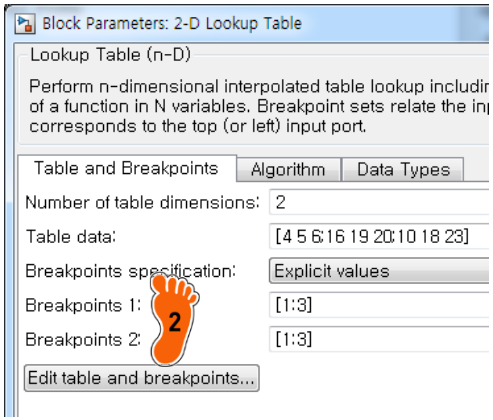
3

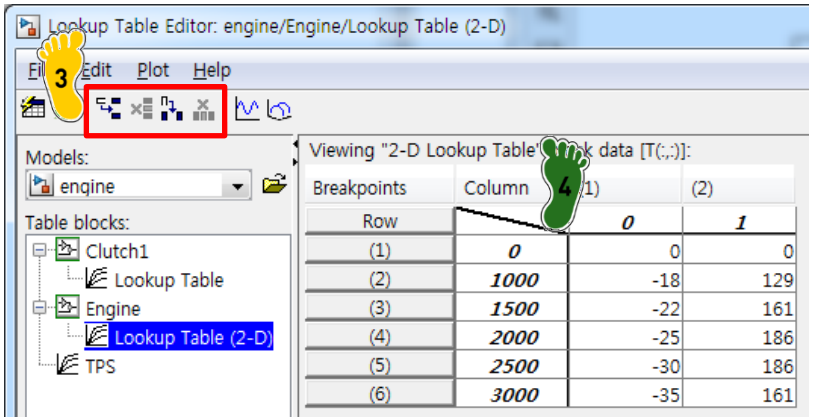
4

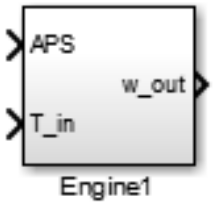
# ENGINE



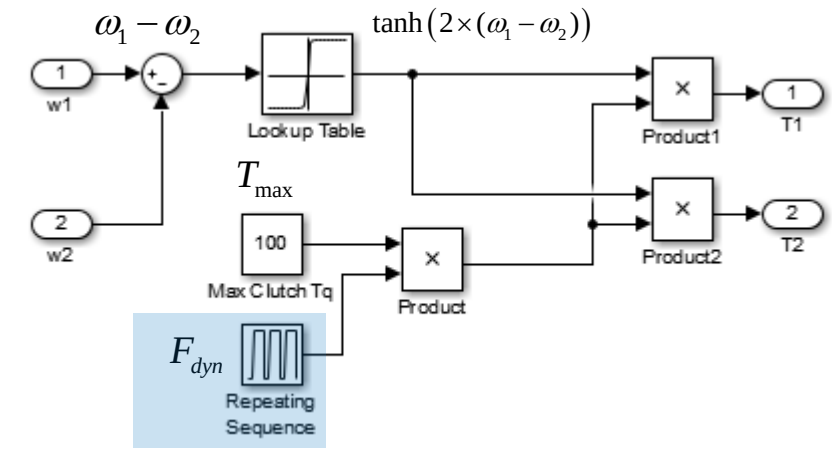



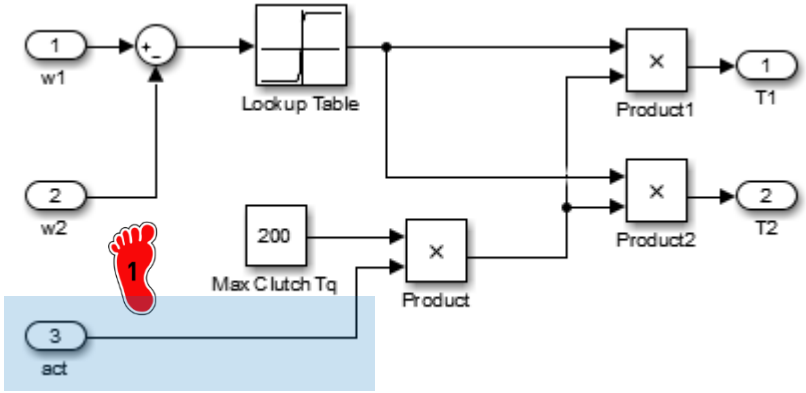




1. 2-D lookup table과 이전에 구성한 inertia subsystem을 이용하여 구성
2. 2-D lookup table 클릭 후 Edit table 클릭
3. toolbox의 add/remove row/column을 이용하여 6X2 table 생성
4. TPS와 RPM 및 torque값 입력, 완료 후 engine subsystem 생성

# ENGINE

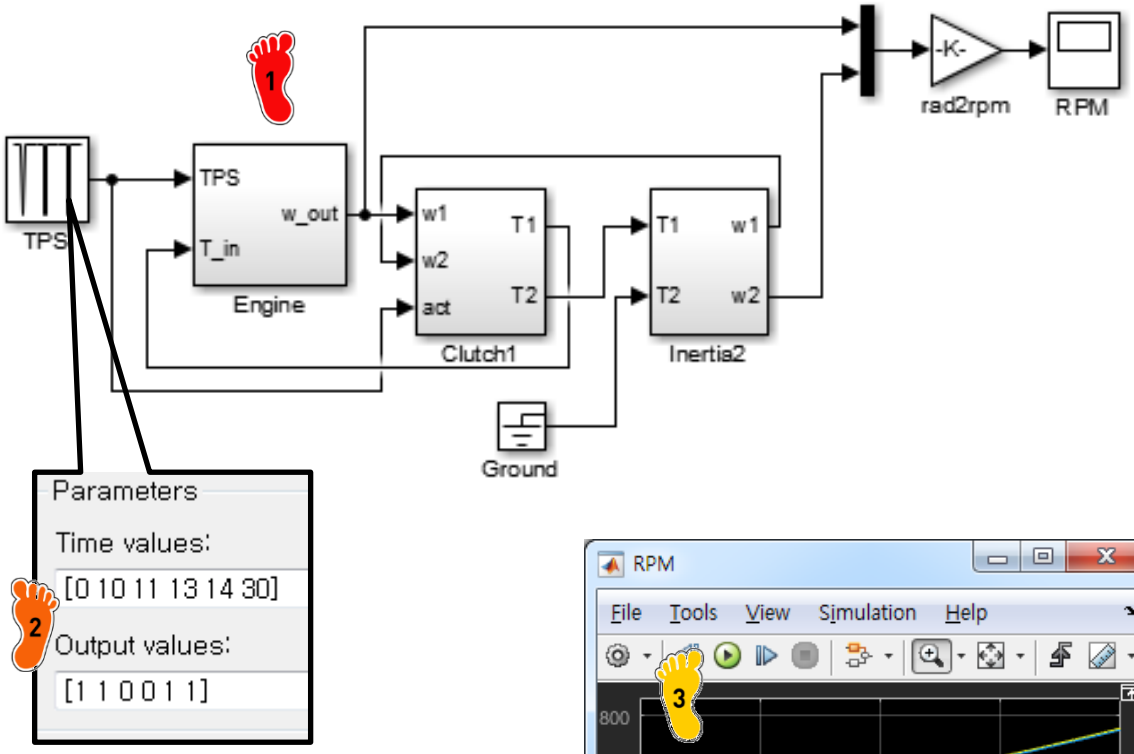


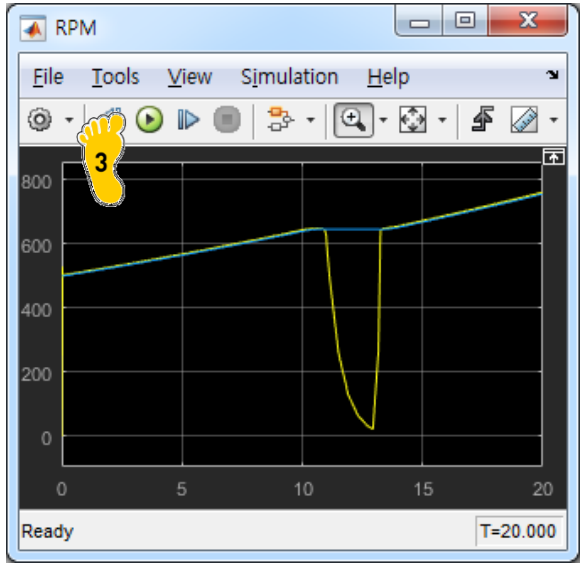





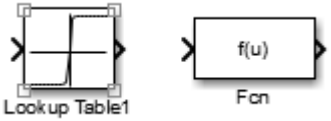
1. 이전에 구성한 clutch model에서 Act. profile 부분 변경 (입력으로 받도록..)
2. clutch subsystem 생성
3.
4.

# ENGINE




※ Clutch Slip Model




Parameters

Expression:

tanh(2*30/pi*u)

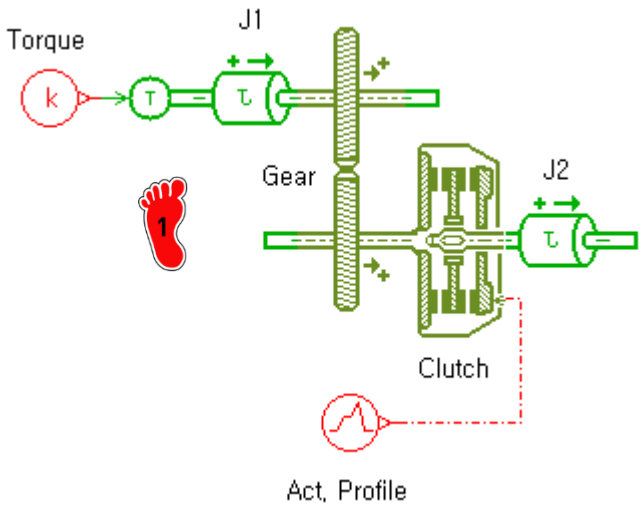
1 전체 block diagram 구성

2 TPS값 입력, clutch profile 은 동일 (AMESim과 반대)

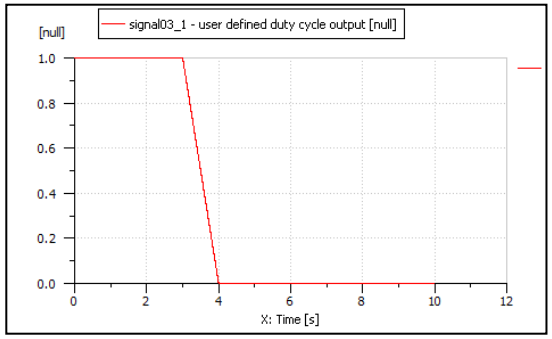
3 Run 및 결과 확인 (20 s)

4

# GEAR




① J1 = 1 kgm^2
② J2 = 1 kgm^2
③ Torque = 1 Nm
④ Clutch = 1000 Nm

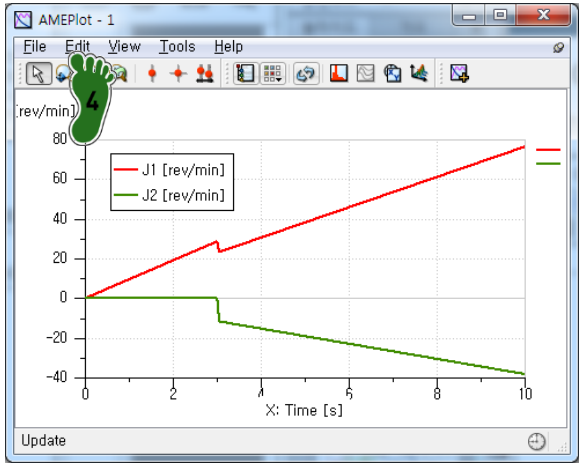



Parameters of gear_3p [TRGT01B-1]

| Title | Value | Unit |
|---|---|---|
| contact assumption | ideal contact | |
| paddling losses | no | |
| working pitch radius | 1 | mm |
| coefficient of viscous friction | 0 | Nm/(rev/min) |

Parameters of gear_3p_1 [TRGT01C-1]

| Title | Value | Unit |
|---|---|---|
| contact stiffness | no stiffness | |
| slipping and rolling losses | no losses | |
| paddling losses | no | |
| working pitch radius | 2 | mm |
| coefficient of viscous friction | 0 | Nm/(rev/min) |



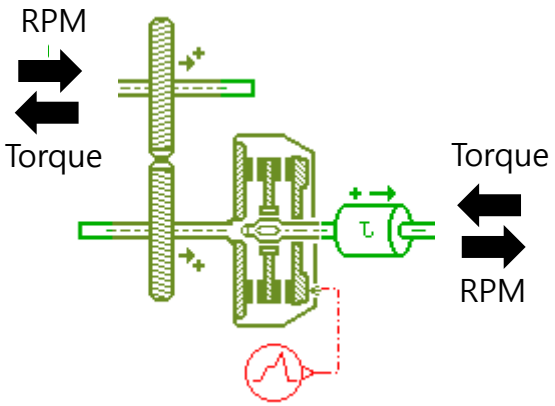

1 Gear 모델 구성

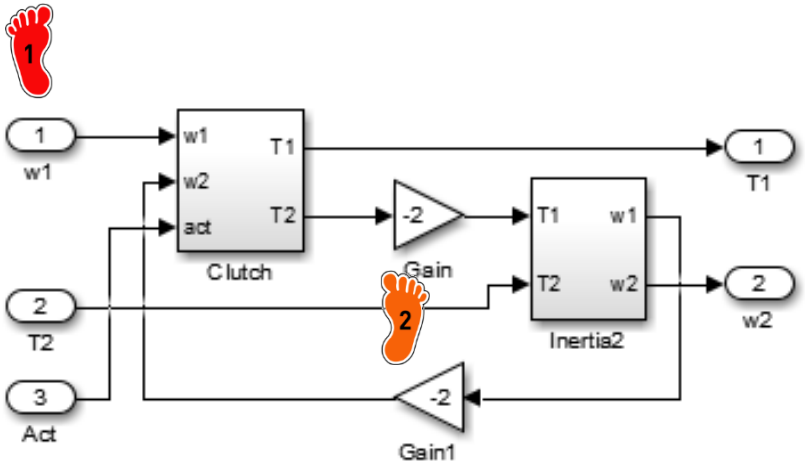
2 J1, J2, Torque, Clutch Parameter, Act. Profile 입력

3 각 기어 모델에 working pitch radius 1 mm, 2 mm 입력

4 Run 및 RPM 결과 확인 (10 s)

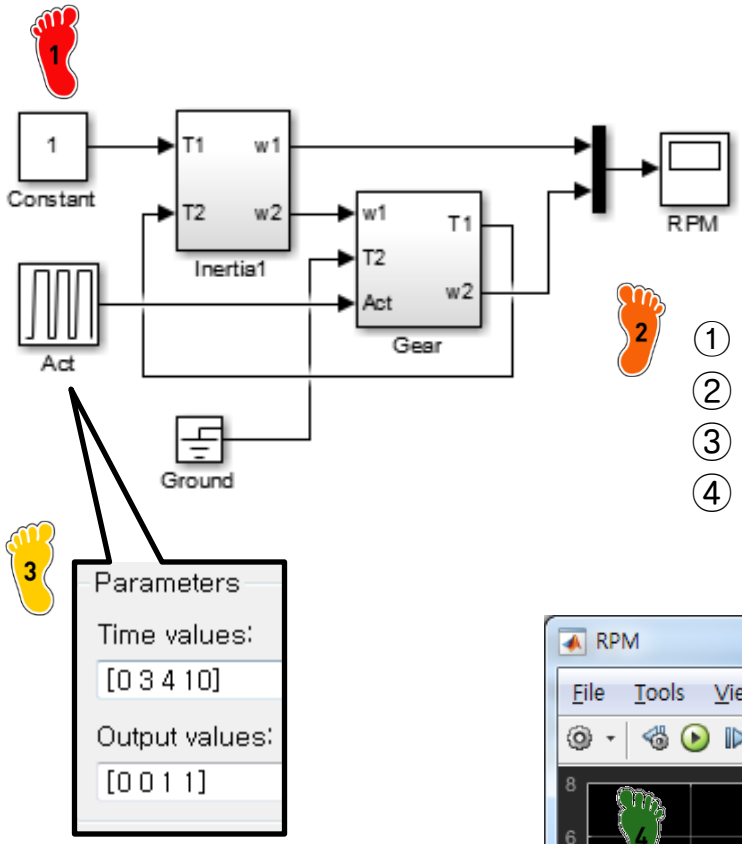
# GEAR



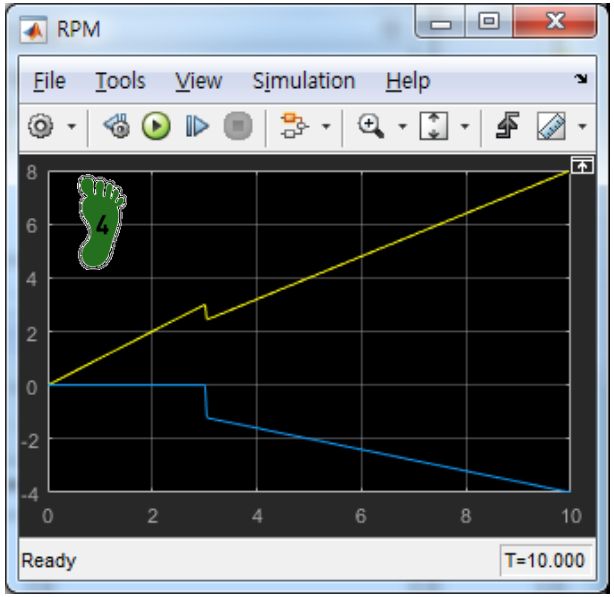

1. Gear 모델 구성
2. Gear ratio 입력 (out/in)
   ⇒ 왜 음수일까??
3. 
4. 

# GEAR




2

① J1 = 1 kgm^2
② J2 = 1 kgm^2
③ Torque = 1 Nm
④ Clutch = 1000 Nm




1 전체 block diagram 구성

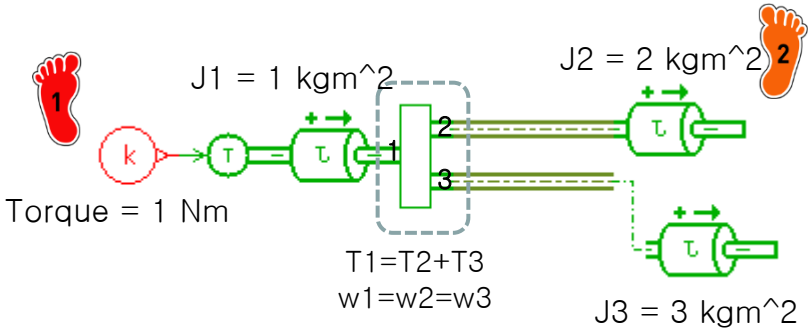
2 각 모델 parameter값 입력

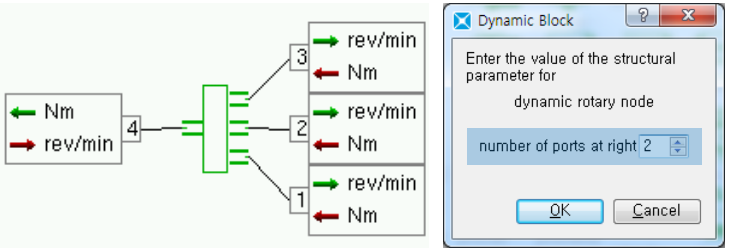
3 Clutch Act. Profile 입력 (AMESim과 반대)

4 Run 및 RPM 결과 확인 (10 s)

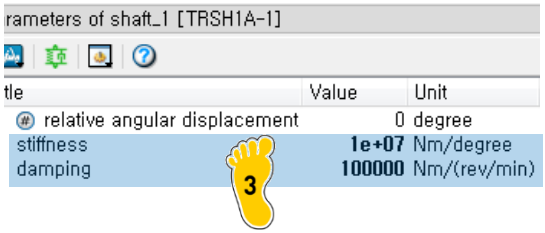
# TRANSMISSION

## Rotary Mechanical Node

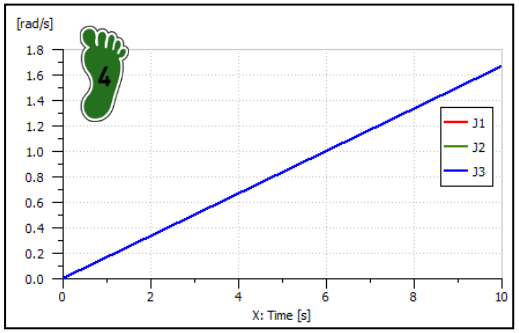


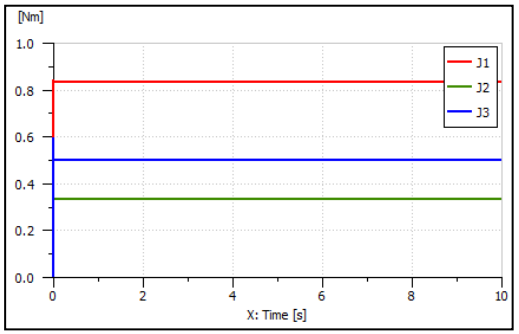








k=1e7, c=1e5

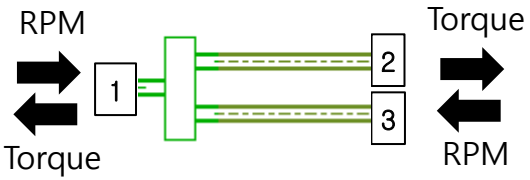


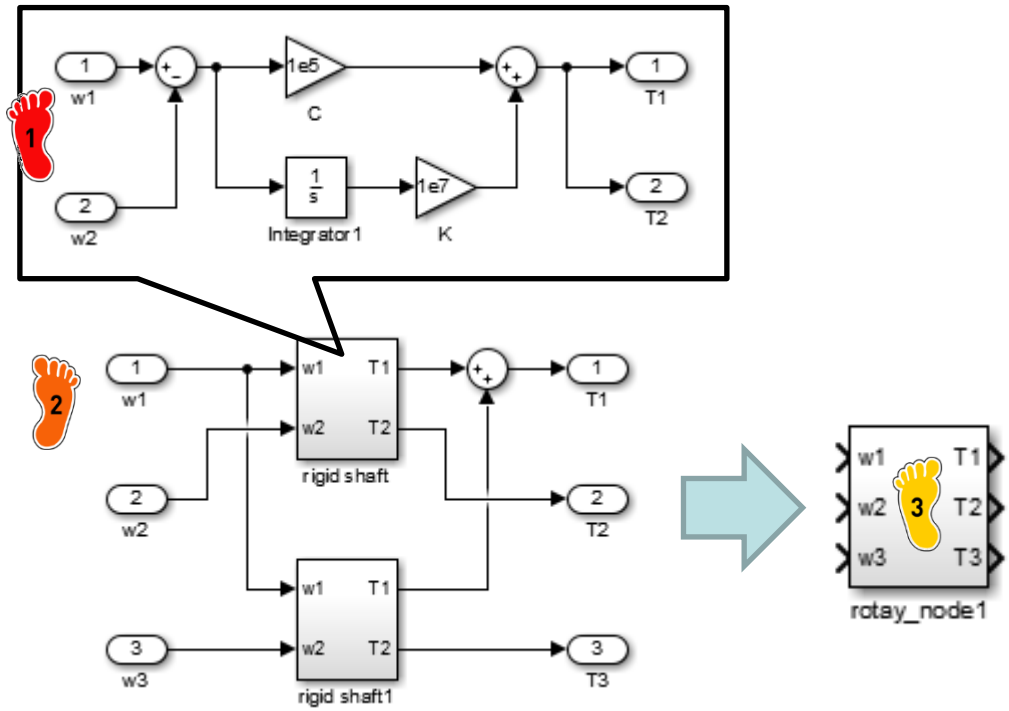




1. 전체 모델 구성 (Rotary Node는 2 port로...)
2. 그림과 같이 Inertia, Torque Parameter 입력
3. Shaft Parameter에 stiffness와 damping값 입력 (rigid shaft를 모사하기 위해 큰 값 입력)
4. Run 및 RPM & Torque 결과 확인 (10 s)

# TRANSMISSION

## Rotary Mechanical Node



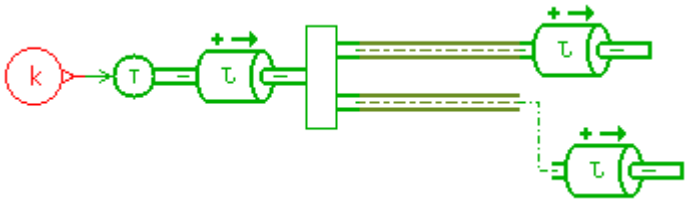



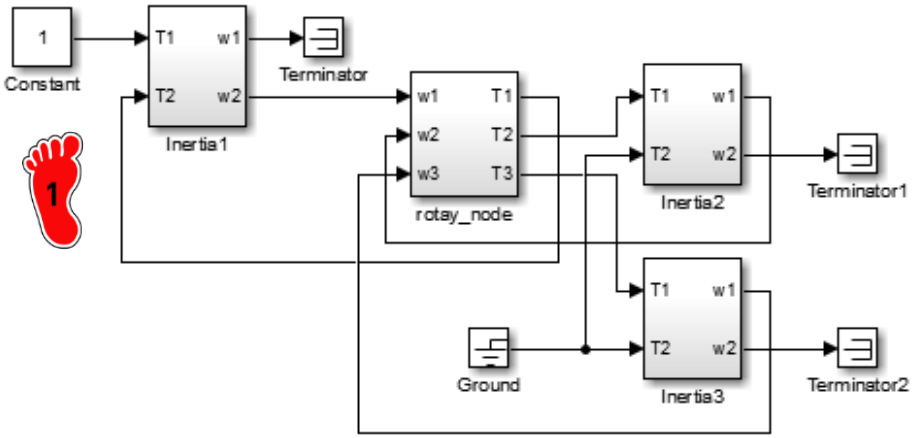

**T1=T2+T3**
**w1=w2=w3**

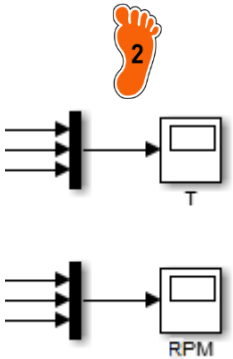
1. rigid shaft 모델 구성 (기존 spring&damper 모델 이용)
2. 전체 모델 구성 (수식 참조)
3. subsystem 생성
4.

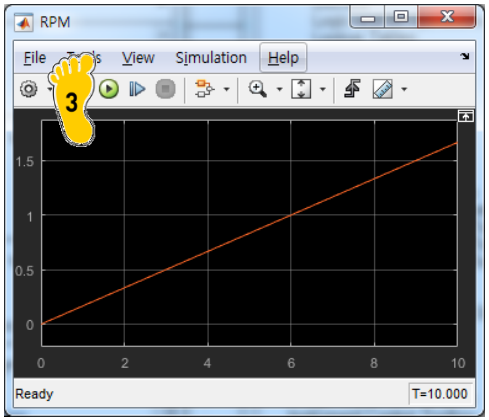
# TRANSMISSION

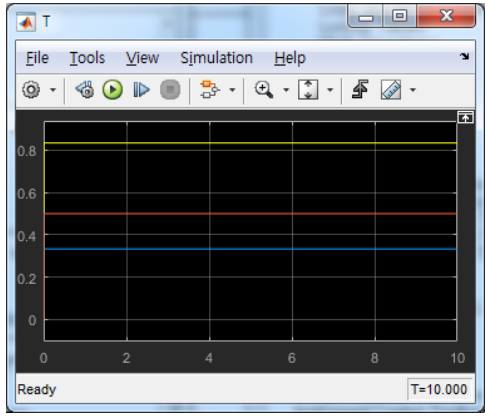
## Rotary Mechanical Node



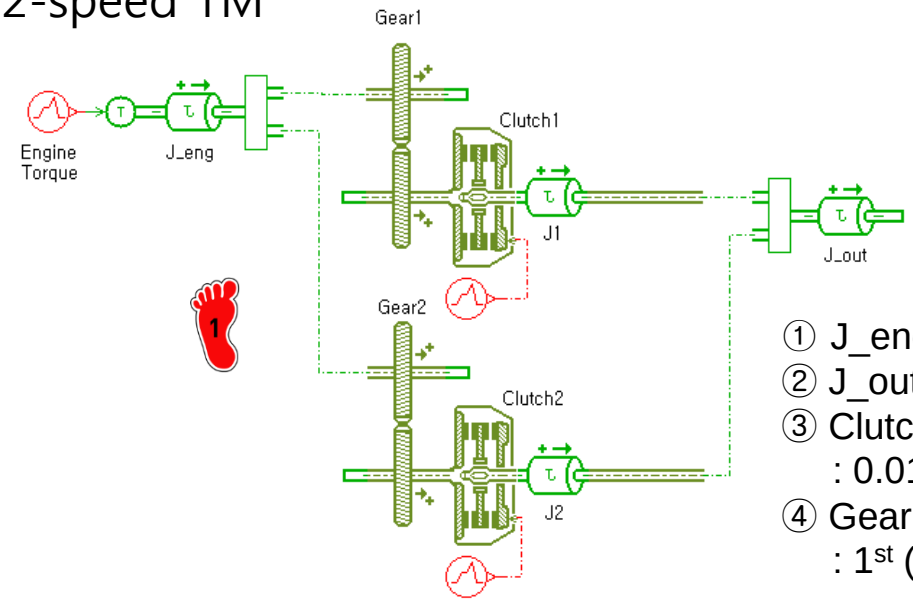




1. 전체 모델 구성
2. 각 이너셔의 RPM과 Torque에 scope 생성
3. Run 및 결과 확인

# TRANSMISSION

## 2-speed TM




① J_eng = 0.1 kgm^2
② J_out = 50 kgm^2
③ Clutch1/2
: 0.01 kgm^2, 1000 Nm
④ Gear Ratio
: 1st (4), 2nd (2)

1 전체 모델 구성

2 각 모델 Parameter 입력 (shaft는 rigid 값 적용)

3 Engine Torque, Clutch Act. profile 입력

4

### Engine Tq.

Parameters of signal03_2 [UD00-1]

| Title | Value | Unit |
|---|---|---|
| number of stages | 2 | |
| cyclic | no | |
| time at which duty cycle st··· | 0 | s |
| output at start of stage 1 | 0 | null |
| output at end of stage 1 | 250 | null |
| duration of stage 1 | 2 | s |
| output at start of stage 2 | 250 | null |
| output at end of stage 2 | 250 | null |
| duration of stage 2 | 1e+06 | s |

### Clutch1

Parameters of signal03 [UD00-2]

| Title | Value | Unit |
|---|---|---|
| number of stages | 4 | |
| cyclic | no | |
| time at which duty cycle st··· | 0 | s |
| output at start of stage 1 | 1 | null |
| output at end of stage 1 | 0 | null |
| duration of stage 1 | 0.2 | s |
| output at start of stage 2 | 0 | null |
| output at end of stage 2 | 0 | null |
| duration of stage 2 | 4.8 | s |
| output at start of stage 3 | 0 | null |
| output at end of stage 3 | 1 | null |
| duration of stage 3 | 0.2 | s |
| output at start of stage 4 | 1 | null |
| output at end of stage 4 | 1 | null |
| duration of stage 4 | 1e+06 | s |

### Clutch2

Parameters of signal03_1 [UD00-3]

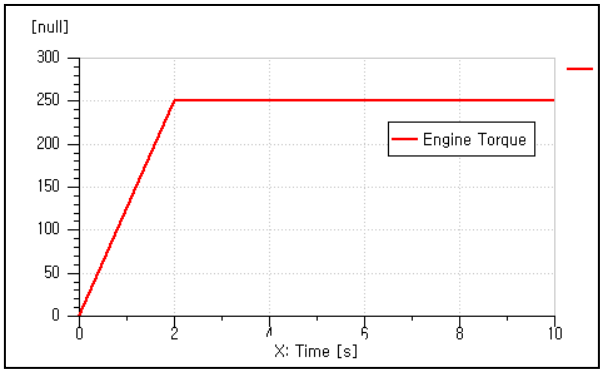
| Title | Value | Unit |
|---|---|---|
| number of stages | 4 | |
| cyclic | no | |
| time at which duty cycle st··· | 5 | s |
| output at start of stage 1 | 1 | null |
| output at end of stage 1 | 0 | null |
| duration of stage 1 | 0.2 | s |
| output at start of stage 2 | 0 | null |
| output at end of stage 2 | 0 | null |
| duration of stage 2 | 4.8 | s |
| output at start of stage 3 | 0 | null |
| output at end of stage 3 | 1 | null |
| duration of stage 3 | 0.2 | s |
| output at start of stage 4 | 1 | null |
| output at end of stage 4 | 1 | null |
| duration of stage 4 | 1e+06 | s |

# TRANSMISSION

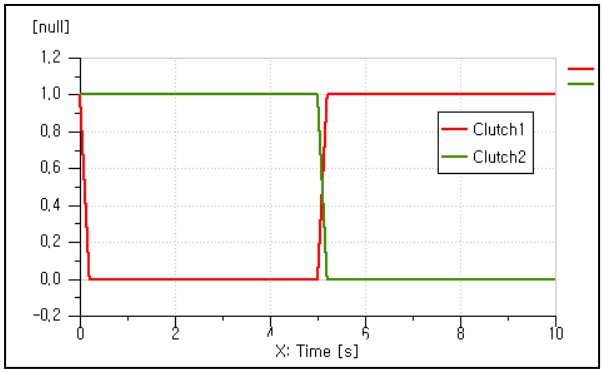
## 2-speed TM

결과 확인

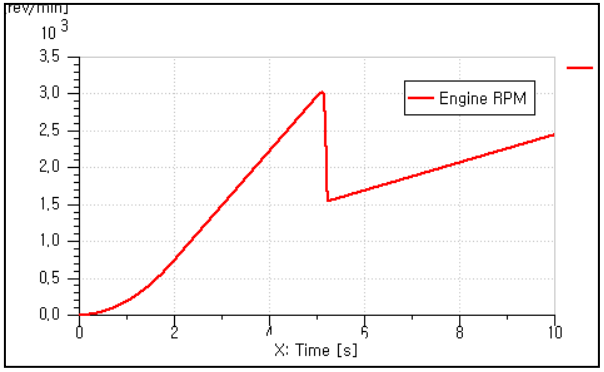
Engine Tq.



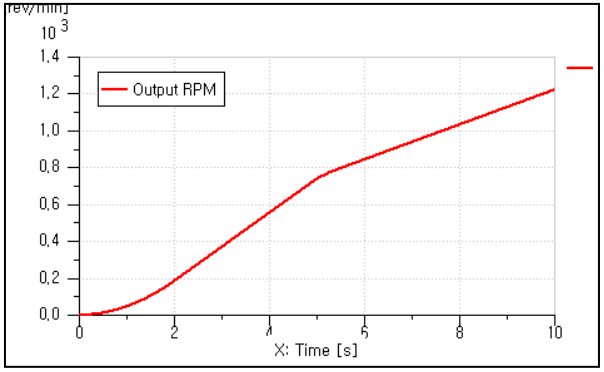

Clutch 1/2




Engine RPM

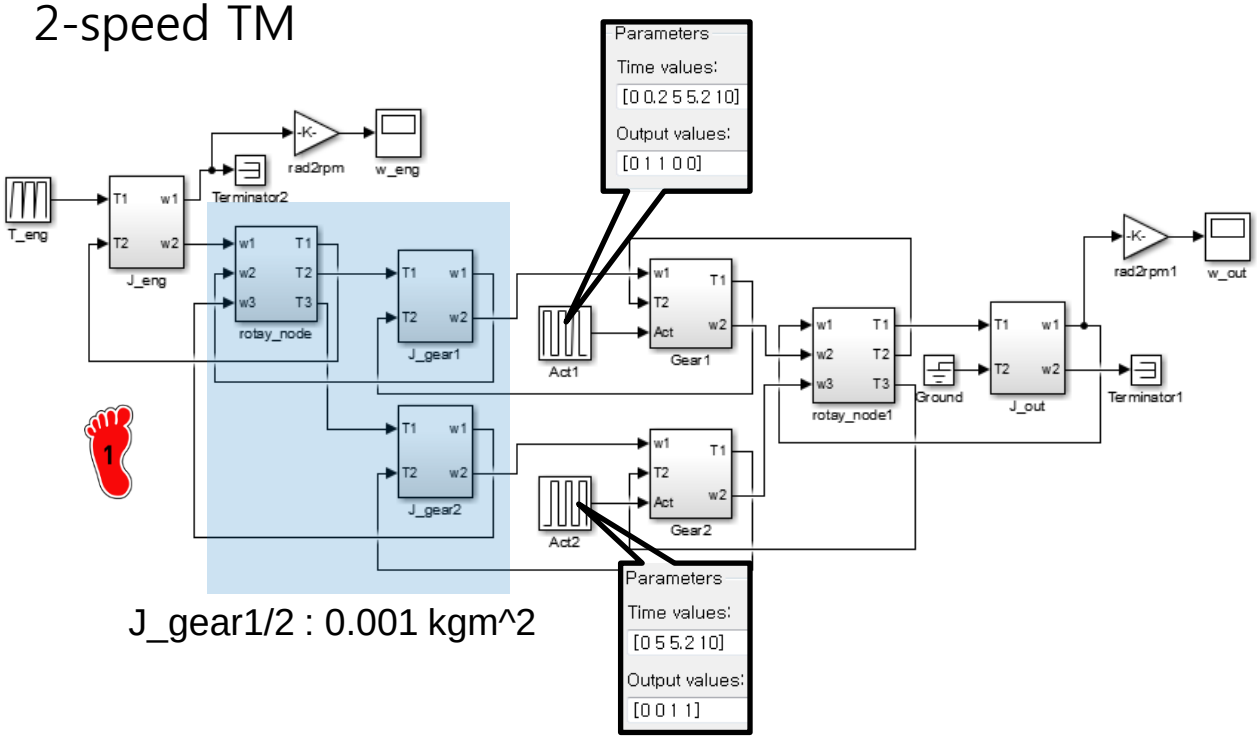



Output RPM

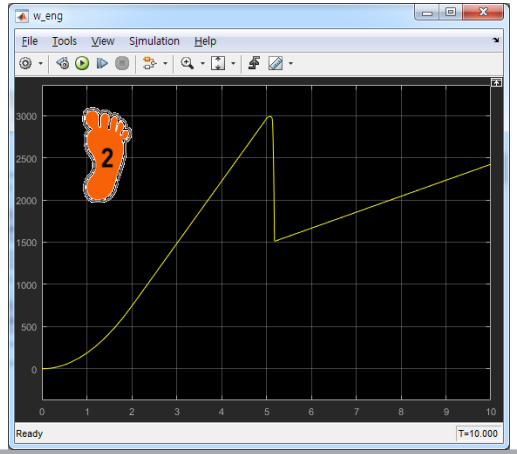


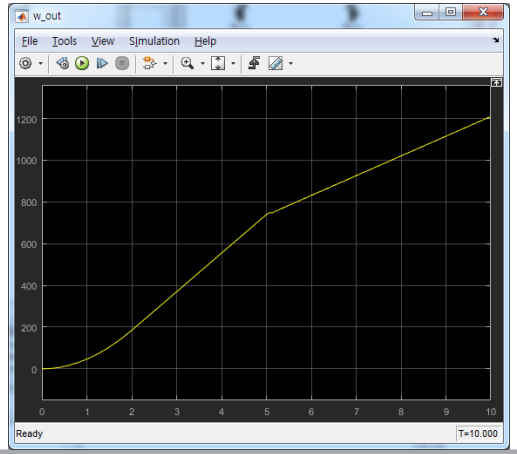
# TRANSMISSION

## 2-speed TM




J_gear1/2 : 0.001 kgm^2




1. 전체 시스템 구성 (AMESim과 다르게 음영부분에 inertia 추가, why?)
2. 결과 확인

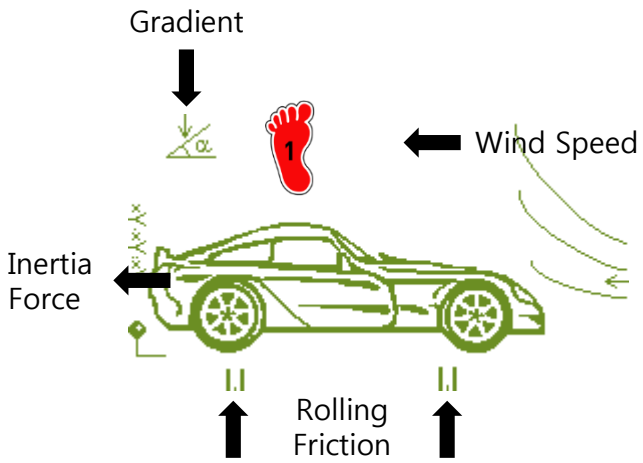
# DRAG FORCE

$$R_d = \frac{1}{2} C_d A_{front} \rho_{air} V_{car}^2$$

$$R_r = \mu_r \times w$$

$$R_g = w \sin \theta_{grad}$$

$$R_a = ma = J_{eq} \alpha_{whl} R_{tire}$$




## Real parameters

| | Title | Variable name | Unit | Default value |
|---|---|---|---|---|
| 1 | carbody mass (including engine block) | mvehi | kg | 1500 |
| 2 | carbody pitch inertia (including engine block) | J | kgm**2 | 800 |
| 3 | total unsprung mass at front | smassF | kg | 40 |
| 4 | total unsprung mass at rear | smassR | kg | 40 |
| 5 | X-position of carbody COG (Grid Frame, including engine block) | xcgp | mm | 1000 |
| 6 | Z-position of carbody COG (Grid Frame, including engine block) | zcgp | mm | 250 |
| 7 | X-position of rear wheel axis (Grid Frame) | xe | mm | 2400 |
| 8 | Z-position of rear wheel axis (Grid Frame) | ze | mm | 0 |
| 9 | Cx - drag coefficient in longitudinal direction | Cx | null | 0.3 |
| 10 | Cz - drag coefficient in vertical direction | Cz | null | 0 |
| 11 | Cm - drag coefficient for pitch | Cm | null | 0 |
| 12 | Sx - frontal area | Sx | m**2 | 1 |
| 13 | air density | rhoair | kg/m**3 | 1.226 |
| 14 | X-position of engine COG (Grid Frame) | Xeng | mm | 1000 |
| 15 | Z-position of engine COG (Grid Frame) | Zeng | mm | 250 |
| 16 | pitch inertia of engine at engine COG | Jeng | kgm**2 | 50 |
| 17 | engine mass | Meng | kg | 120 |
| 18 | X-position of the COR (Grid Frame) | Xrefg | mm | 0 |
| 19 | Z-position of the COR (Grid Frame) | Zrefg | mm | 0 |
| 20 | Z-position of front wheels centers (Road Frame) | Zo | m | 0.3 |
| 21 | windage coefficient in longitudinal direction | rwvehx | N/(m/s)**2 | 0.6 |
| 22 | windage coefficient in vertical direction | rwvehz | N/(m/s)**2 | 0 |
| 23 | windage coefficient for pitch | rwvehy | N/(m/s)**2 | 0 |

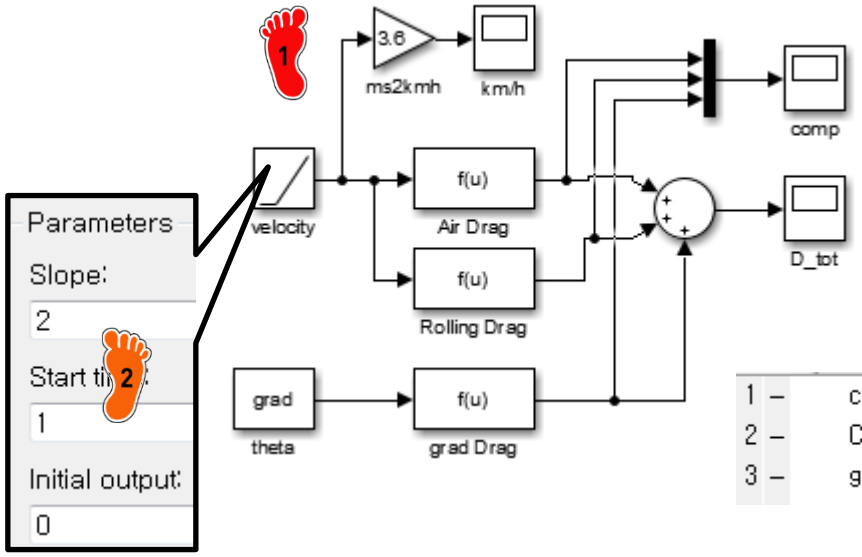
1 powertrain library 내 vehicle model 제공

2 longitudinal외 vertical, pitch현상 같이 표현 (입력변수 많음, 생략)

3

4

# DRAG FORCE




```
1 –    clear all; close all;
2 –    Cd=0.25; A=2; mu_roll=0.01;
3 –    grad=0.5*pi/180; M_body=1500;
```

3

작업 공간

| 이름 | 값 |
|---|---|
| A | 2 |
| Cd | 0.2500 |
| grad | 0.0087 |
| M_body | 1500 |
| mu_roll | 0.0100 |

$$R_d = \frac{1}{2} C_d A_{front} \rho_{air} V_{car}^2$$

2

Parameters

Expression:

0.5*Cd*A*1.226*u^2

$$R_r = \mu_r \times w$$

2

Parameters

Expression:

mu_roll*M_body*9.81*tanh(u)

$$R_g = w \sin \theta_{grad}$$

2

Parameters

Expression:

M_body*9.81*sin(u)

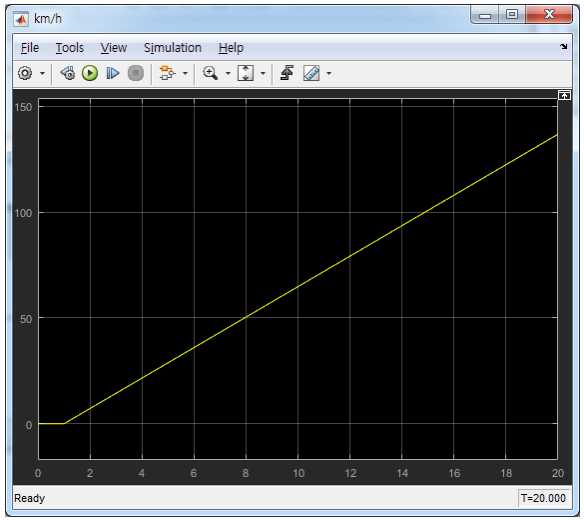
1 전체 모델 구성

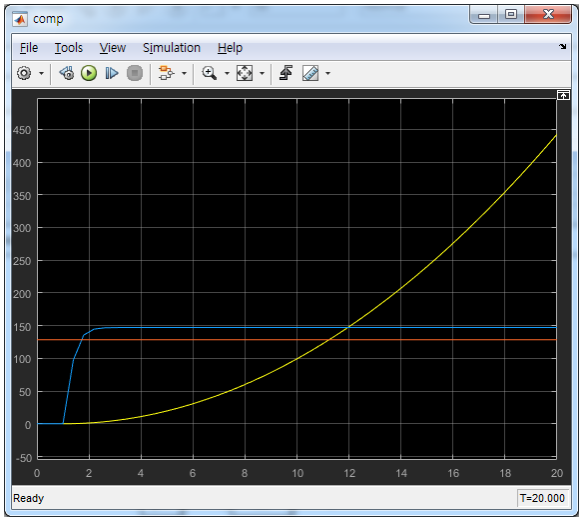
2 속도 parameter와 drag 계산식 입력

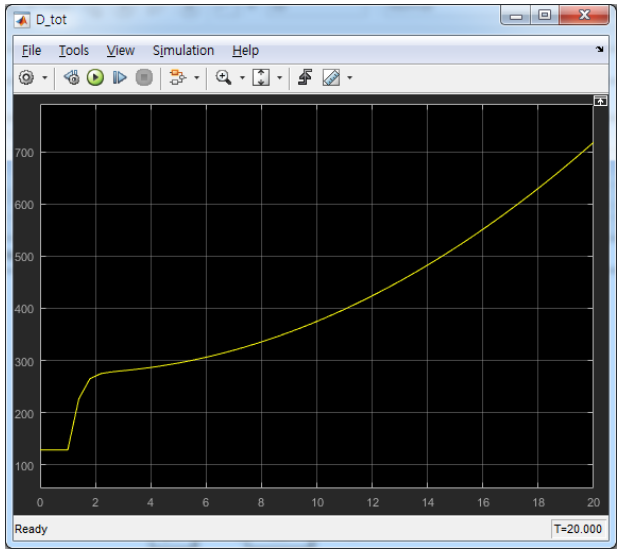
3 작업공간에 parameter 값 정의

4

# DRAG FORCE



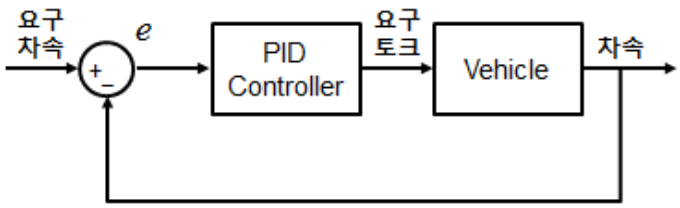

1 Run 및 결과 확인(20 s)

2

3

4

# DRIVER CONTROLLER



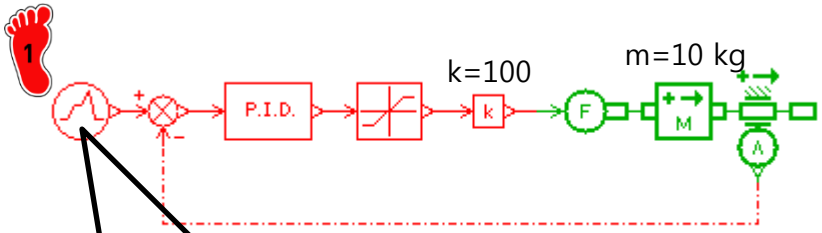

$$T_{req} = K_p e(t) + K_i \int e(t)\,dt + K_d \frac{de(t)}{dt} \quad \begin{cases} e(t) \geq 0 : \text{accelation} \\ e(t) < 0 : \text{braking} \end{cases}$$

$$(e(t) = V_{req.} - V_{real})$$

$K_p$ : proportional gain

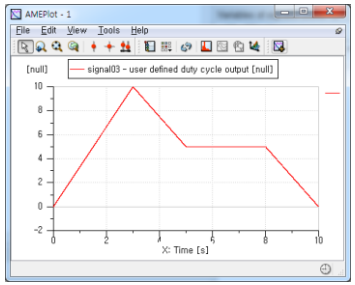
$K_i$ : integral gain

$K_d$ : differential gain




| Title | Value | Unit |
|---|---|---|
| number of stages | 5 | |
| cyclic | no | |
| time at which duty cycle starts | 0 | s |
| output at start of stage 1 | 0 | null |
| output at end of stage 1 | 10 | null |
| duration of stage 1 | 3 | s |
| output at start of stage 2 | 10 | null |
| output at end of stage 2 | 5 | null |
| duration of stage 2 | 2 | s |
| output at start of stage 3 | 5 | null |
| output at end of stage 3 | 5 | null |
| duration of stage 3 | 3 | s |
| output at start of stage 4 | 5 | null |
| output at end of stage 4 | 0 | null |
| duration of stage 4 | 2 | s |
| output at start of stage 5 | 0 | null |
| output at end of stage 5 | 0 | null |
| duration of stage 5 | 1e+06 | s |


| Title | Value | Unit |
|---|---|---|
| minimum permitted value | −1 | null |
| maximum permitted value | 1 | null |




1 제어 모델 구성

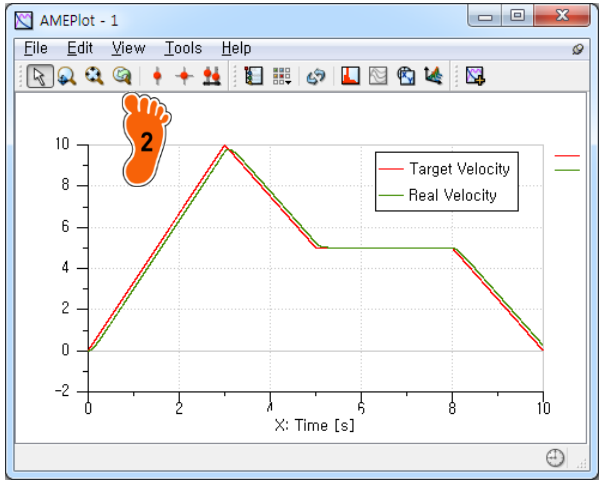
2 요구 속도, 요구 힘, 질량 값 입력

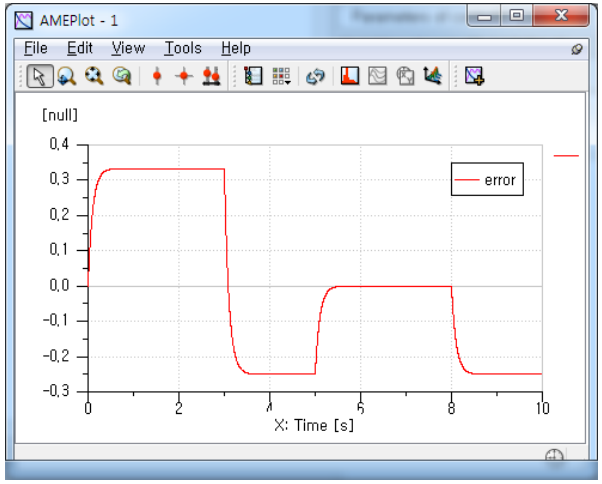
3

4

# DRIVER CONTROLLER

| Title | Value | Unit |
|---|---|---|
| dummy state variable for estimati··· | 0 | 1/s |
| integral part | 0 | null |
| controller type | PID | |
| limit output | no | |
| proportional gain | 1 | null |
| integral gain | 0 | null |
| derivative gain | 0 | null |
| time constant for first order lag used t··· | 0,001 | null |



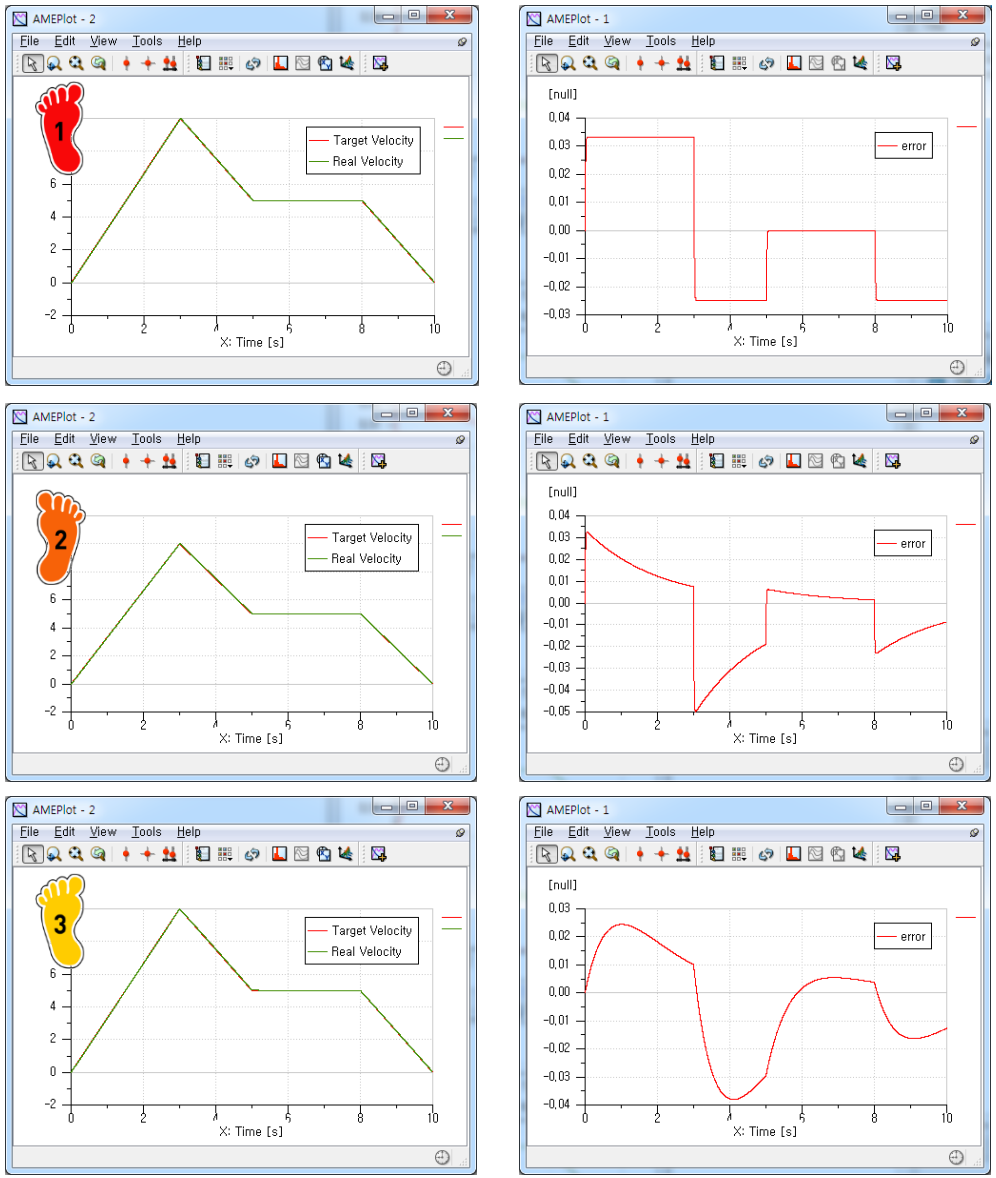

1 Kp=1, Ki=0, Kd=0

2 요구 속도, 실제 속도 확인
error값 확인

3

4

# DRIVER CONTROLLER



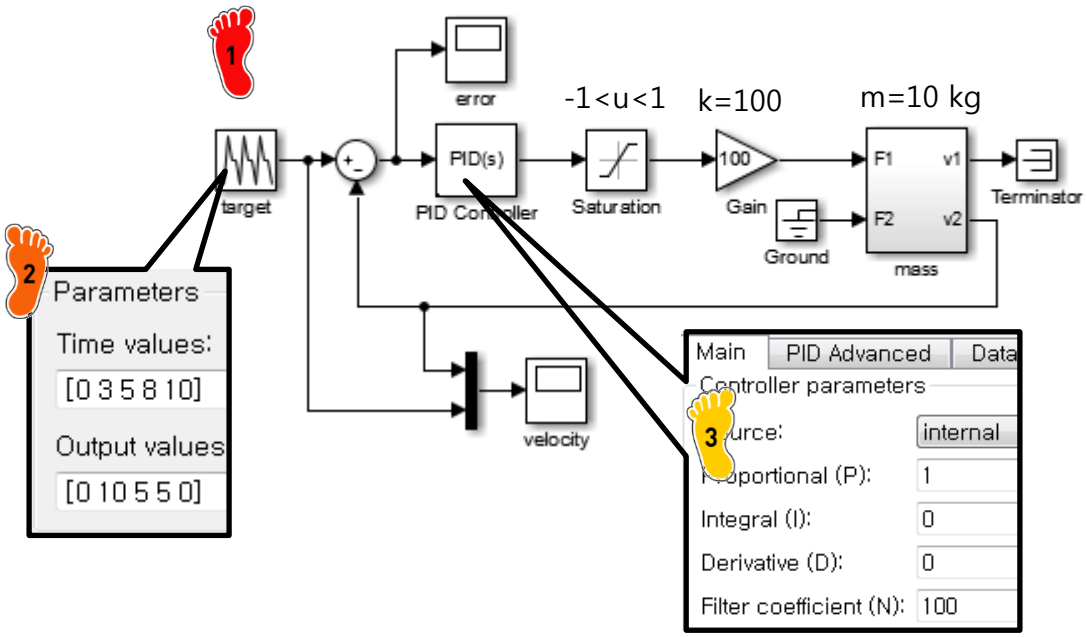

1 Kp=10, Ki=0, Kd=0

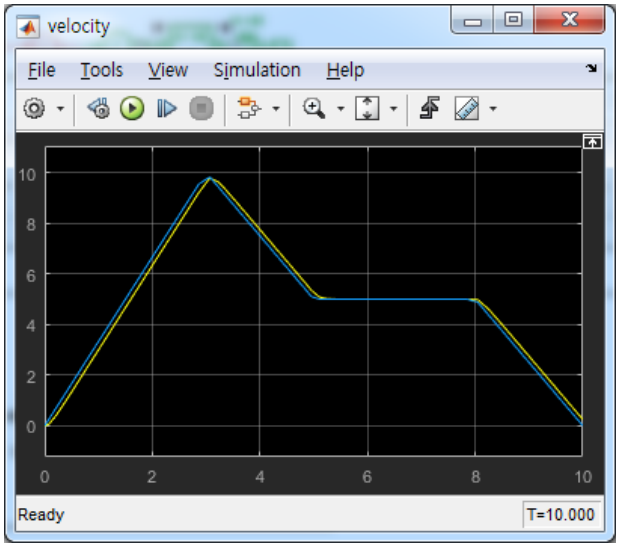
2 Kp=10, Ki=5, Kd=0

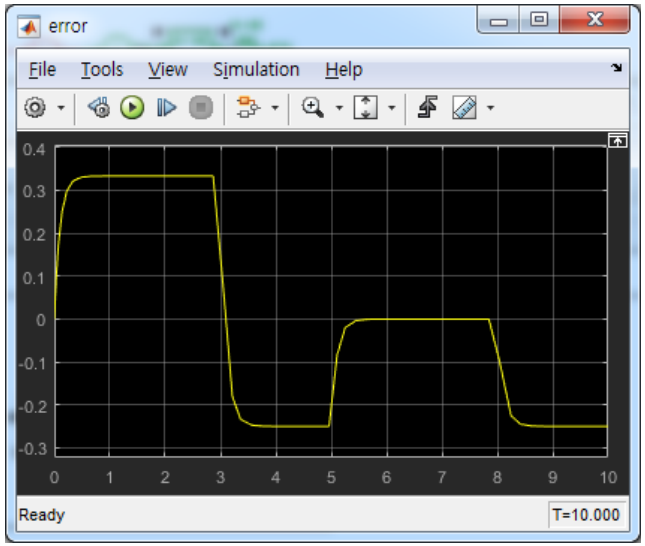
3 Kp=10, Ki=5, Kd=5

4

# DRIVER CONTROLLER




1 제어 모델 구성

2 요구 속도, 요구 힘, 질량 값 입력

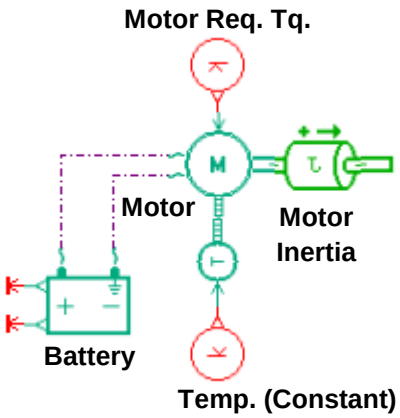
3 Kp, Ki, Kd값의 변화에 의한 결과 확인

4

# ASSIGNMENT

## Electric Power System Modeling : Battery & Simple Motor (by Simulink)

### 1. Reference Model (AMESim)




**Battery**

Parameters of drv_battery_2 [DRVBAT03-1]

| Title | Value | Unit |
|---|---|---|
| potential at port 2 | 122 | V |
| state of charge at port 4 | 50 | % |
| number of cells in series per battery bank | 1 | |
| number of battery banks in parallel | 1 | |
| number of battery banks in series | 1 | |
| discontinuity handling | active | |
| tables dependencies | state of charge (SOC) | |
| rated capacity of the battery | 108.3 | Ah |
| voltage time constant | 0.5 | s |
| filename for open circuit voltage (for one cell) [··· | CAE/ocv.data | |
| filename for internal resistance (for one cell) [··· | CAE/resistance.data | |

**OCV**

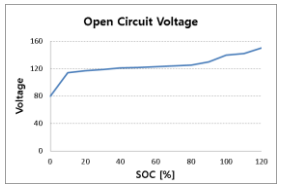
Format: 1D Table

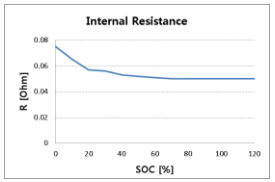
| | X1 | Y |
|---|---|---|
| 1 | 0 | 0.075 |
| 2 | 10 | 0.065 |
| 3 | 20 | 0.057 |
| 4 | 30 | 0.056 |
| 5 | 40 | 0.053 |
| 6 | 50 | 0.052 |
| 7 | 60 | 0.051 |
| 8 | 70 | 0.05 |
| 9 | 80 | 0.05 |
| 10 | 90 | 0.05 |
| 11 | 100 | 0.05 |

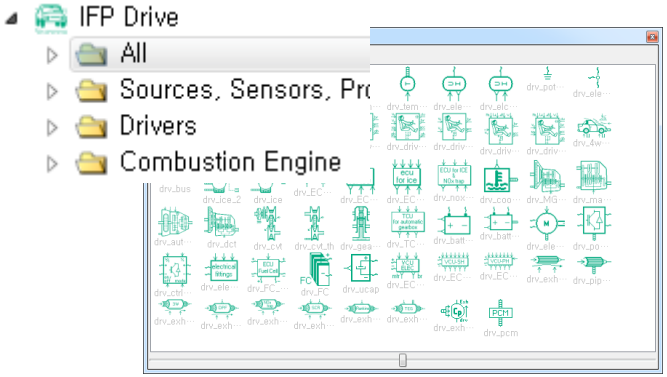
**Resistance**

Format: 1D Table

| | X1 | Y |
|---|---|---|
| 1 | 0 | 80 |
| 2 | 10 | 114 |
| 3 | 20 | 117 |
| 4 | 30 | 119 |
| 5 | 40 | 121 |
| 6 | 50 | 122 |
| 7 | 60 | 123 |
| 8 | 70 | 124 |
| 9 | 80 | 125 |
| 10 | 90 | 130 |
| 11 | 100 | 140 |




① T_motor = 100 Nm
② J_motor = 100 kgm$^2$
③ Motor Temp. = 25 deg

**Motor**

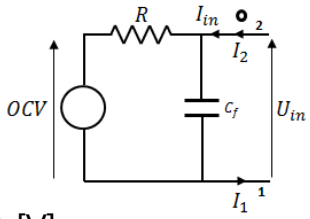
Parameters of drv_electricmotortherm [DRVELMT0A-1]

| Title | Value | Unit |
|---|---|---|
| motor torque at port 2 | 0 | Nm |
| data type for electric motor modeling | constant values | |
| time constant to determine the torque | 0.1 | s |
| maximum power | 15000 | W |
| maximum torque | 150 | Nm |
| mean efficiency | 1 | null |
| maximum rotary velocity | 8000 | rev/min |

# ASSIGNMENT

## 2. SOC calculation

$$V = V_0 - RI$$




$V$ : output volatage [V]

$V_0$ : open circuit voltage [V]

$R$ : equivalent internal resistance [Ohm]

$I$ : input current [A]

$$\frac{dSOC}{dt} = -\frac{dq}{dt} \bullet \frac{100}{C_{nom}} \ [\%]$$

$SOC$ : state of charge [%]

$C_{nom}$ : rated capacity [As]

$$SOC = SOC_{initial} - \int I\,dt \bullet \frac{100}{C_{nom}} [\%]$$

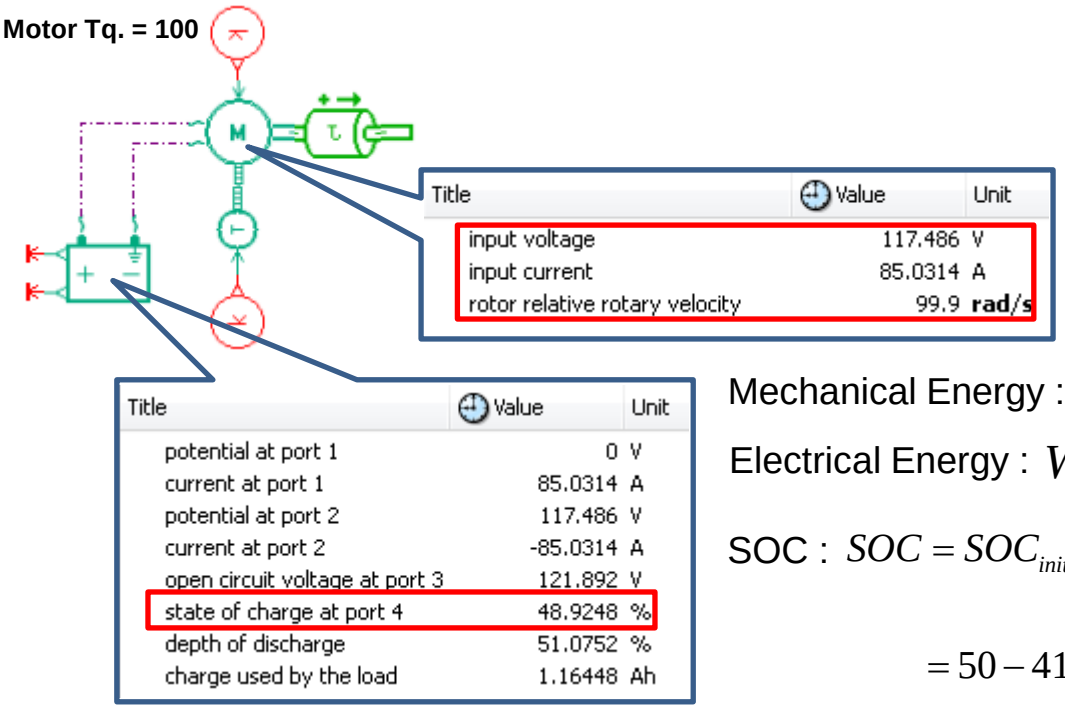
$$W_{motor} = Tw = VI \text{ (without losses)}$$

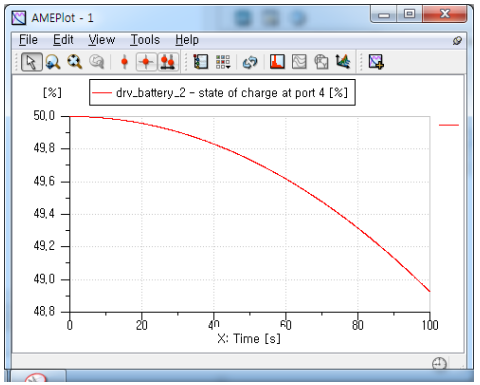
Mechanical Energy : $W = Tw$

Electrical Energy : $W = VI$

### 2) **Result (Simulation Time : 100 s)**

**Motor Tq. = 100**




Mechanical Energy : $W_{mec} = Tw = 100 \times 99.9 = 9990\ W$

Electrical Energy : $W_{elec} = VI = 117.49 \times 85.03 = 9990\ W$

SOC : $SOC = SOC_{initial} - \int I\,dt \bullet \frac{100}{C_{nom}} [\%]$

$$= 50 - 4192.02 \frac{100}{108.3 \times 3600} = 48.925\ \%$$