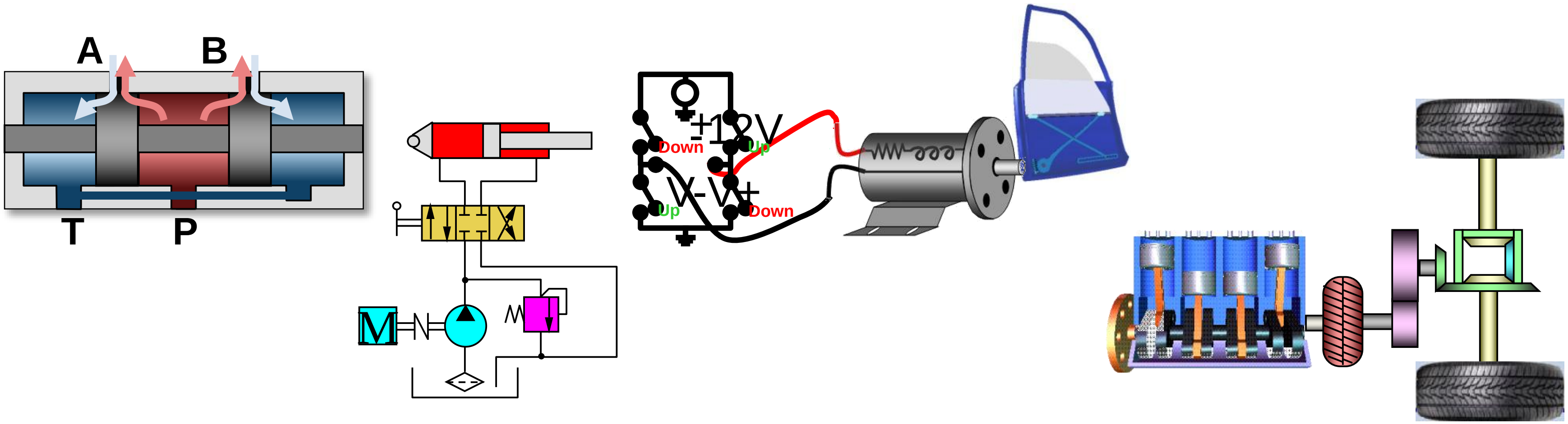
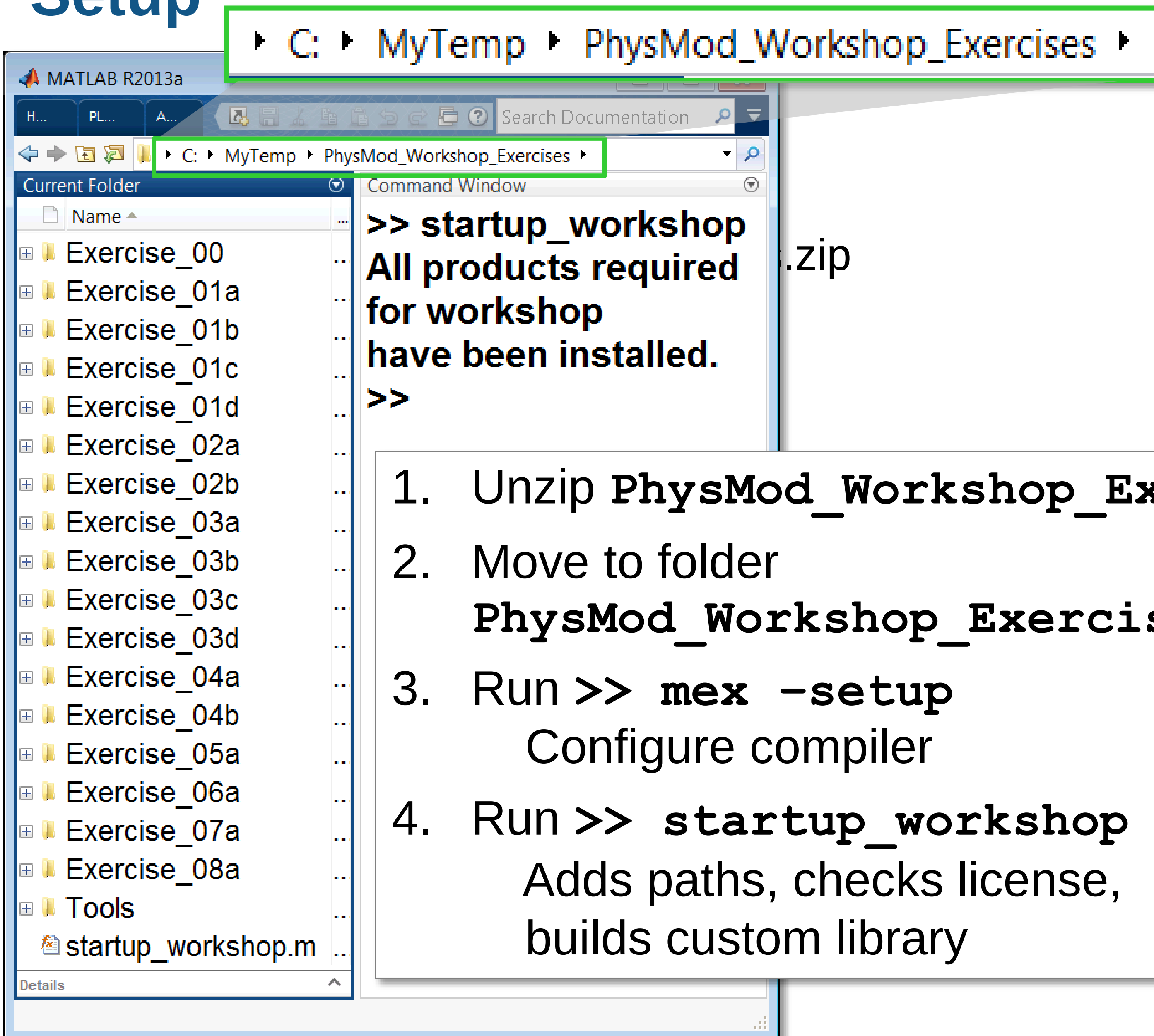
Modeling and Simulation of Physical Systems with Physical Modeling



Hands-on Workshop

Setup



1. Unzip **`PhysMod_Workshop_Exercises.zip`**
2. Move to folder **`PhysMod_Workshop_Exercises`**
3. Run >> **`mex -setup`**
   Configure compiler
4. Run >> **`startup_workshop`**
   Adds paths, checks license, builds custom library

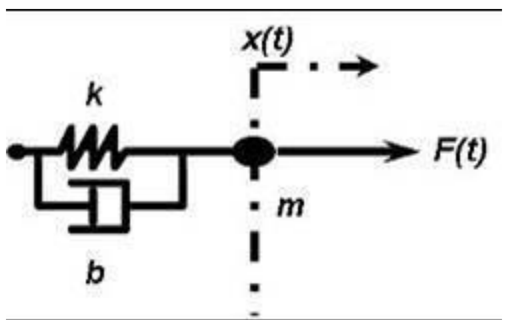
Exercises

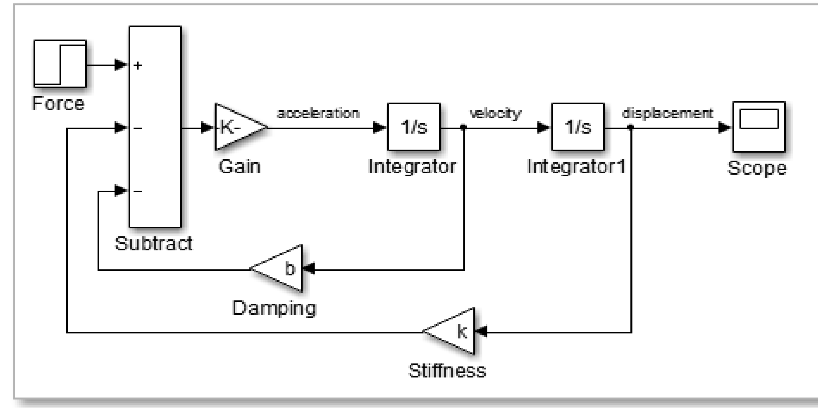
Exercise

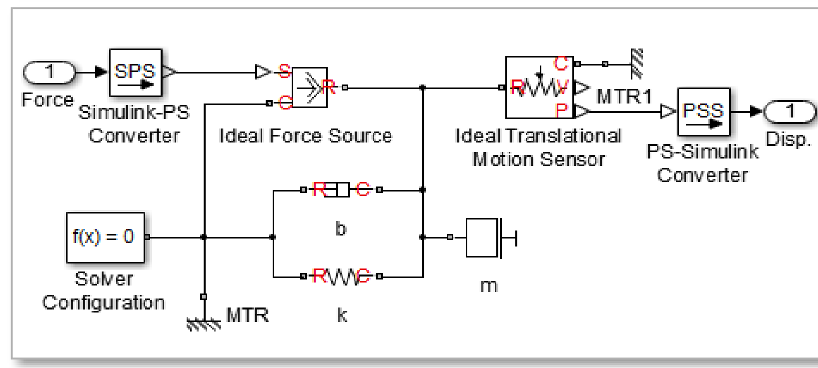
Exercise 0: Introduction to the Physical Modeling Tools
Exercise 1a: Using Simscape to model a DC Motor
Exercise 1b: Using Simulink Parameter Estimation to tune parameters
Exercise 1c: Using Simulink Response Optimization to optimize system performance
Exercise 1d: Using Simscape to model a four-way directional valve
Exercise 2a: Using SimMechanics to model a power window mechanism
Exercise 2b: Connecting a DC motor to a SimMechanics window mechanism
Exercise 3a: Using SimDriveline to model a drivetrain with a clutch
Exercise 3b: Using SimDriveline to model a vehicle powertrain
Exercise 3c: Adding a four-speed transmission and controller to a powertrain model
Exercise 3d: Using SimDriveline to model a ratchet leadscrew mechanism
Exercise 4a: Using SimHydraulics to model a hydraulic actuation system
Exercise 5a: Using Simscape and SimElectronics to model a position control system
Exercise 6a: Using SimPowerSystems to model a PWM controlled motor
Exercise 7a: Using the Simscape language to model custom mechanical springs
Exercise 8a: Using SimMechanics to model a slider-crank mechanism

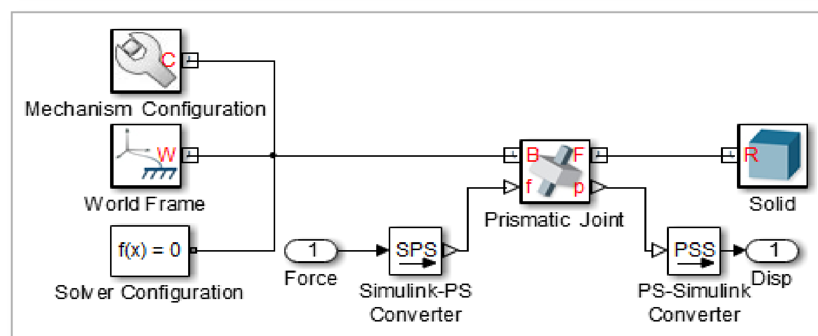
Exercise 0: 1 DOF Mass-Spring-Damper System

Model:







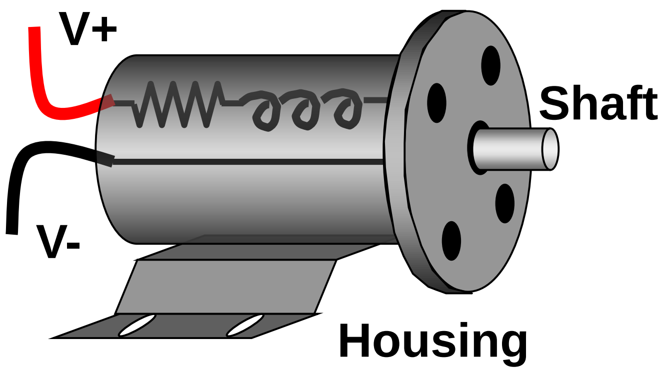


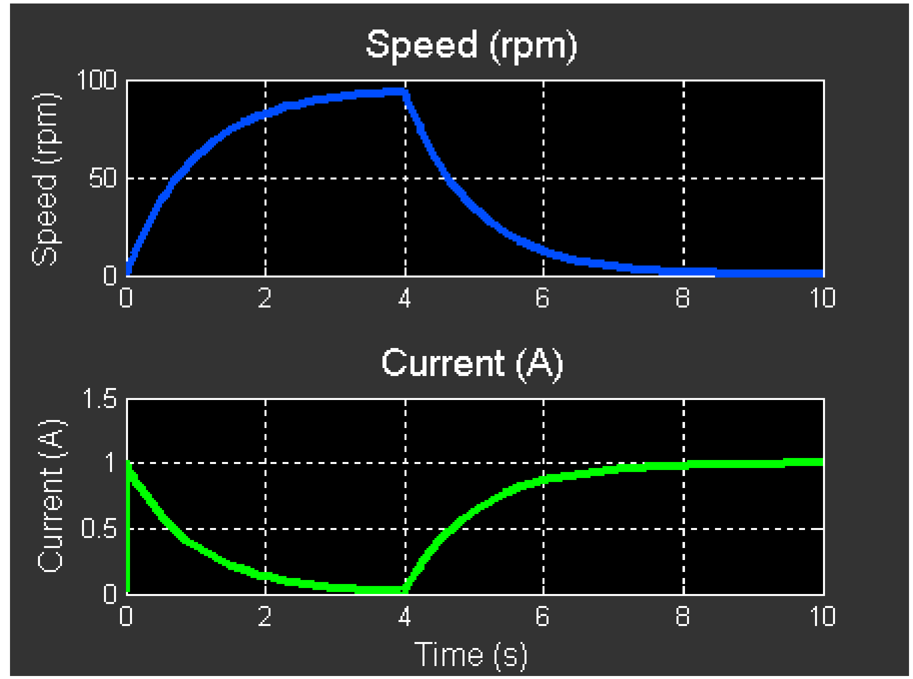
Problem: Model a 1 DOF mass-spring-damper system within the Simulink environment from first principles and using physical modelling tools.

Solution: Use Simulink, Simscape, or SimMechanics.

Exercise 1a: DC Motor

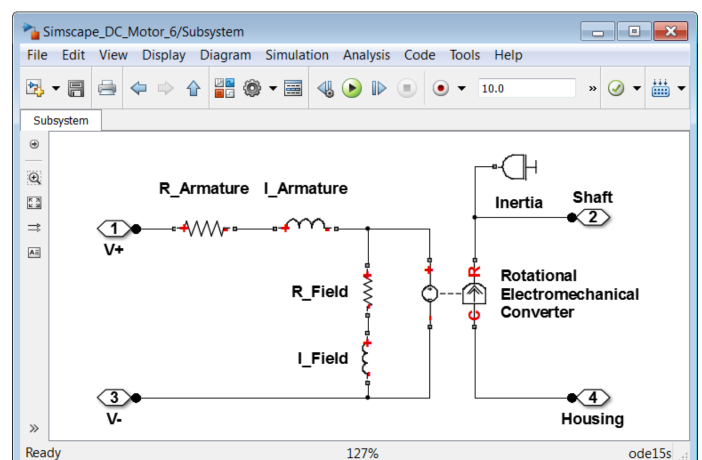
Model:





Problem: Model a DC motor in a reusable way within the Simulink environment

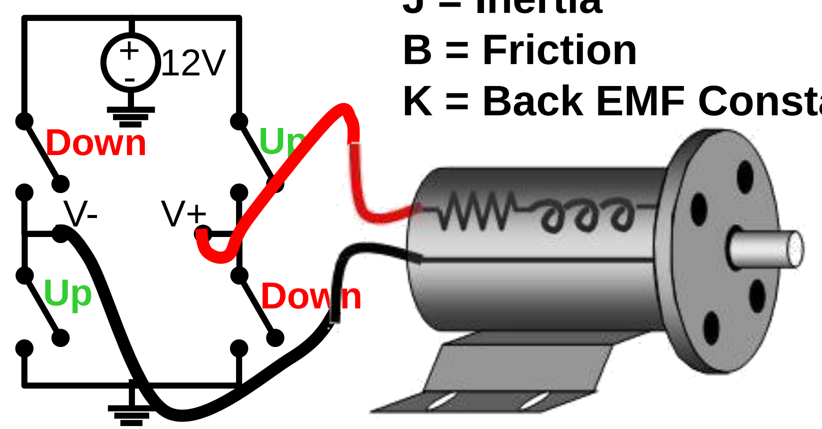
Solution: Use Simscape to model the electromechanical system

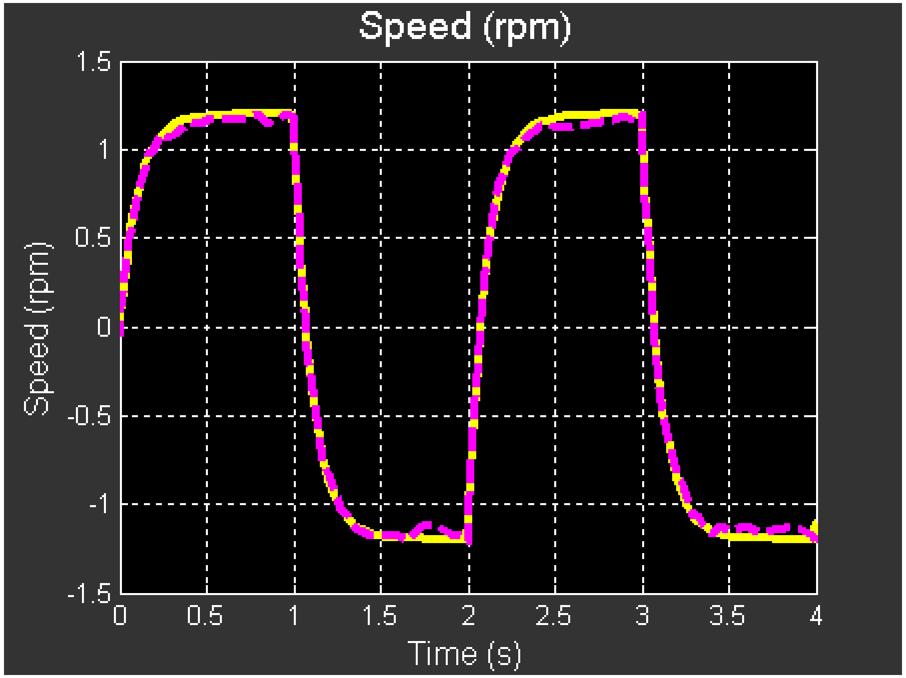


Exercise 1b: Estimating Model Parameters

Model:

R = Resistance
L = Inductance
J = Inertia
B = Friction
K = Back EMF Constant





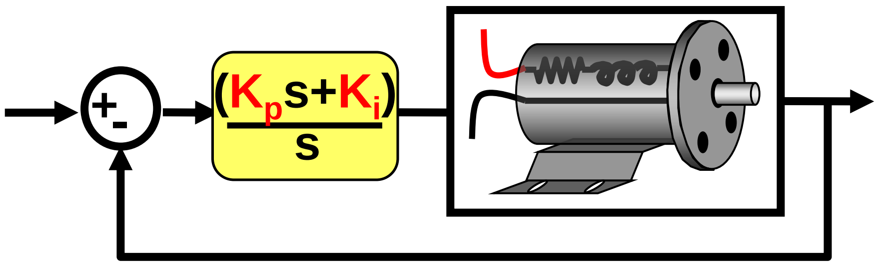
Problem: Simulation data does not match measured data because the parameters are incorrect

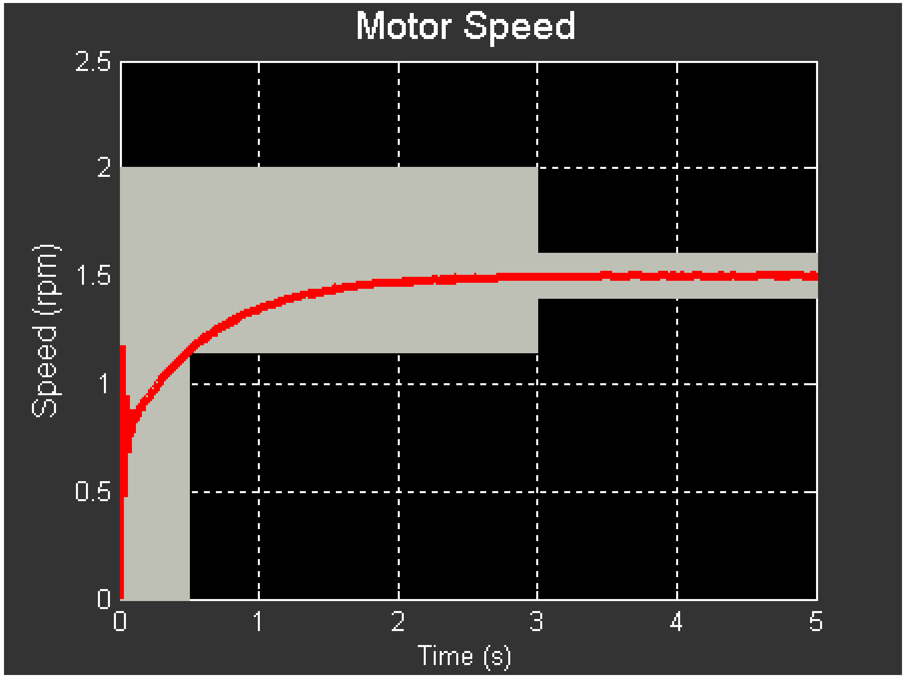
R	L	J	K	B
4.03	1e-4	0.11	0.45	1.07

Solution: Use Simulink Design Optimization to automatically tune model parameters

Exercise 1c: Optimizing Performance

Model:





Problem: Design and tune the controller in this system to meet system requirements

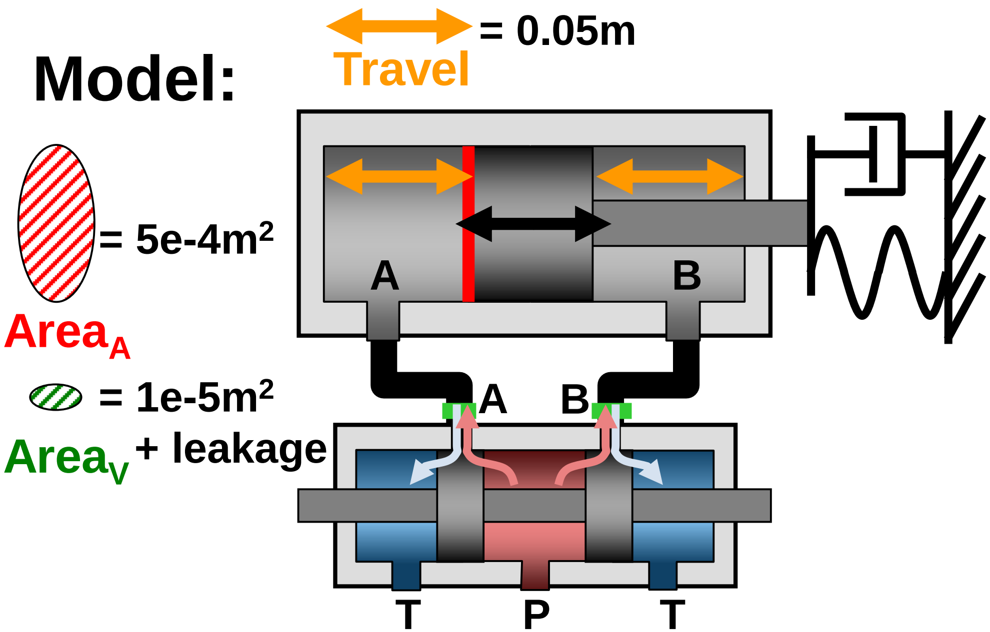
Solution: Use Simulink Response Optimization to design, tune, and test the controller

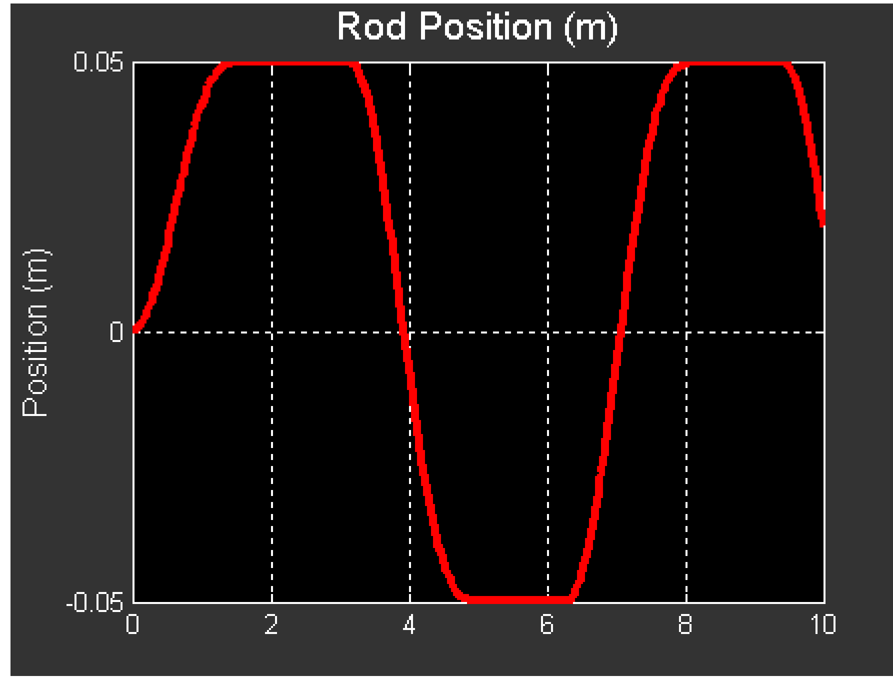
$$\frac{(K_p s+K_i)}{s}$$

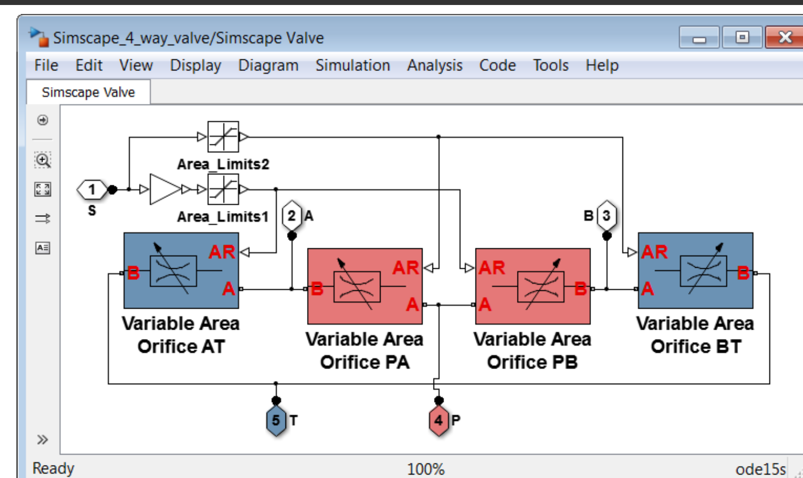
K_p	K_i
14.39	1.336

Exercise 1d: Four-Way Valve

Model:





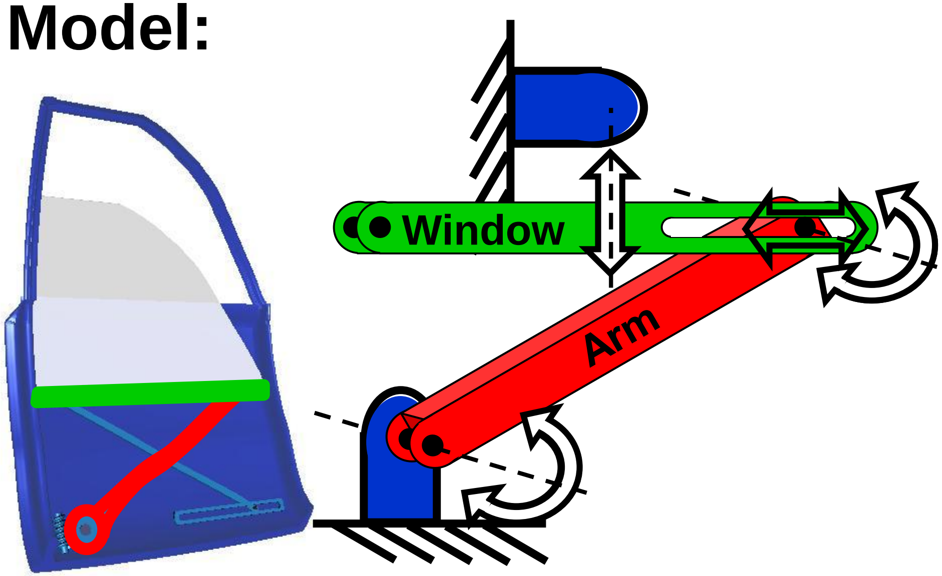


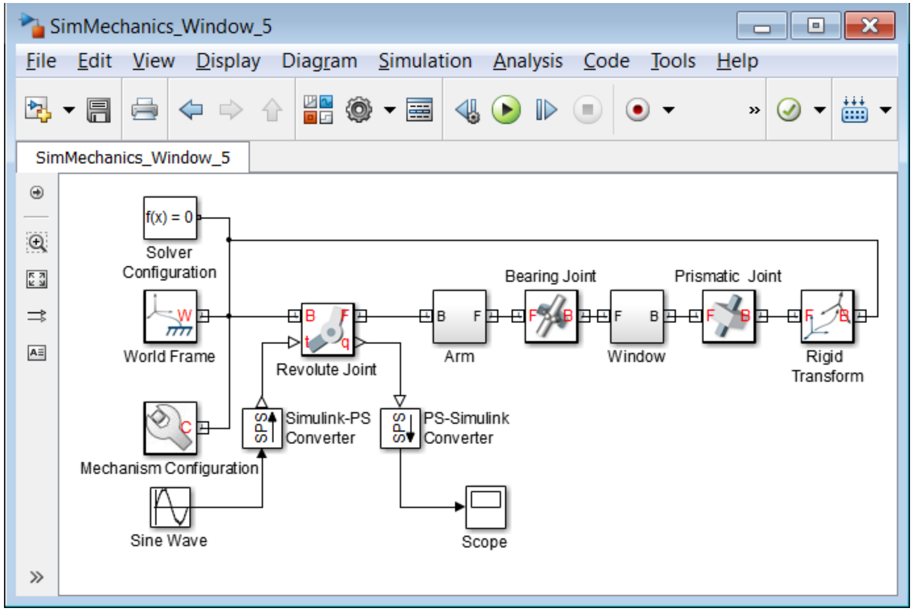
Problem: Model a four-way directional valve and double-acting cylinder within the Simulink environment

Solution: Use Simscape to model the four-way directional valve

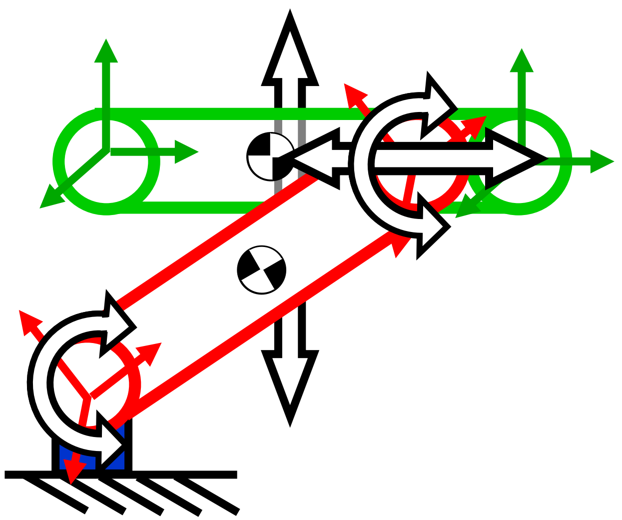
Exercise 2a: Window Mechanism

Model:





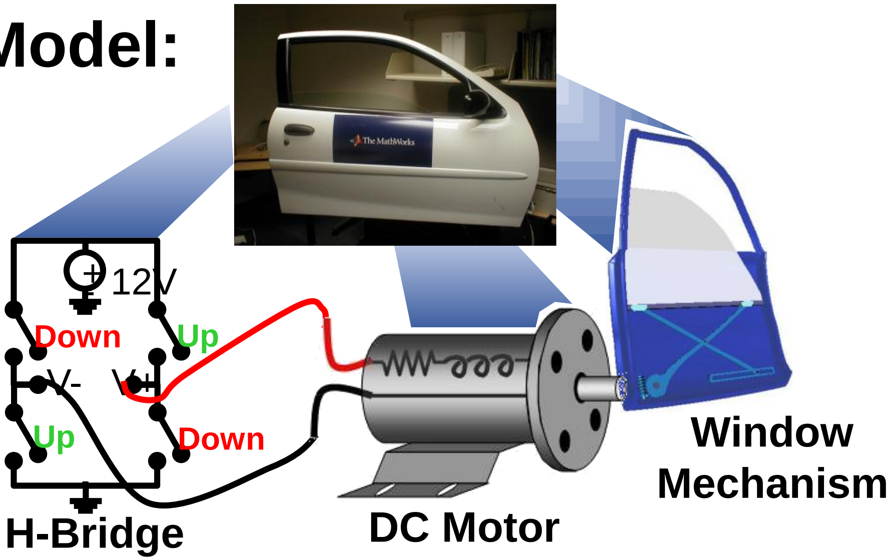
Problem: Model a window mechanism in a reusable way within the Simulink environment.

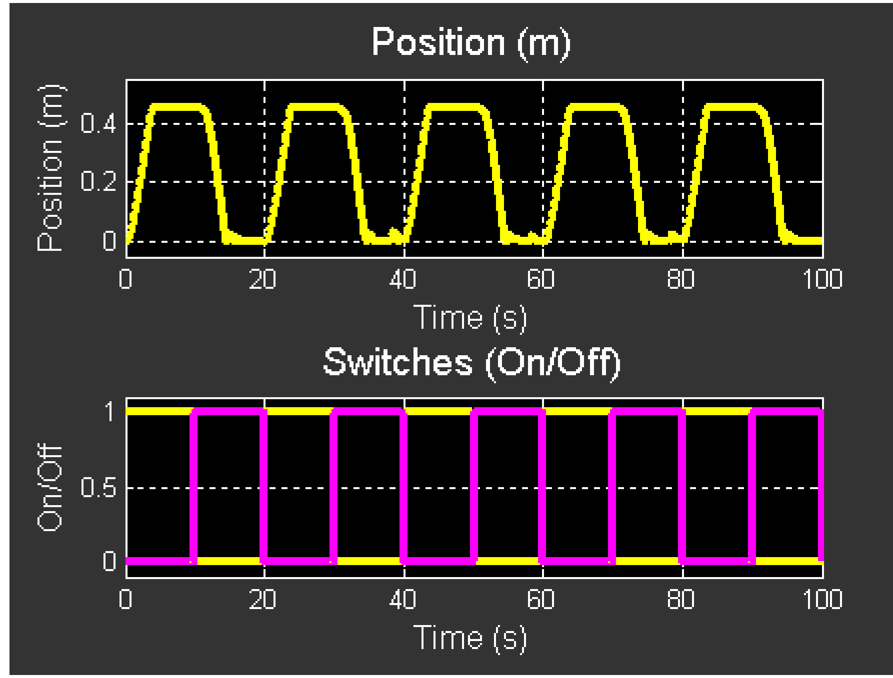


Solution: Use SimMechanics to model the mechanical system.

Exercise 2b: Power Window Mechanism

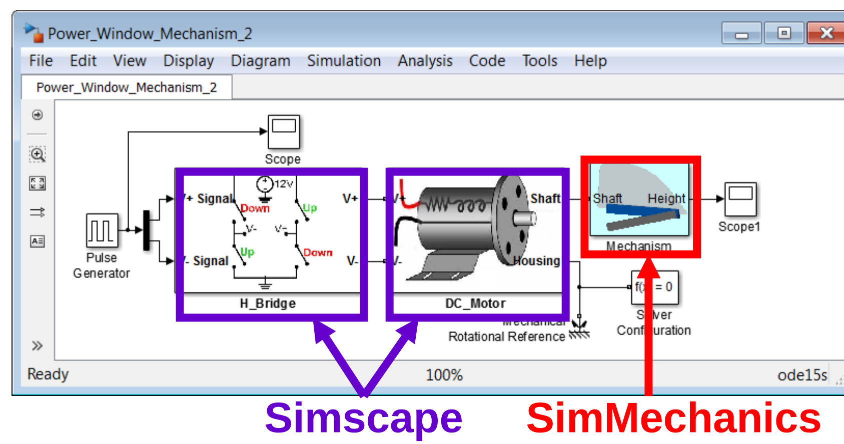
Model:





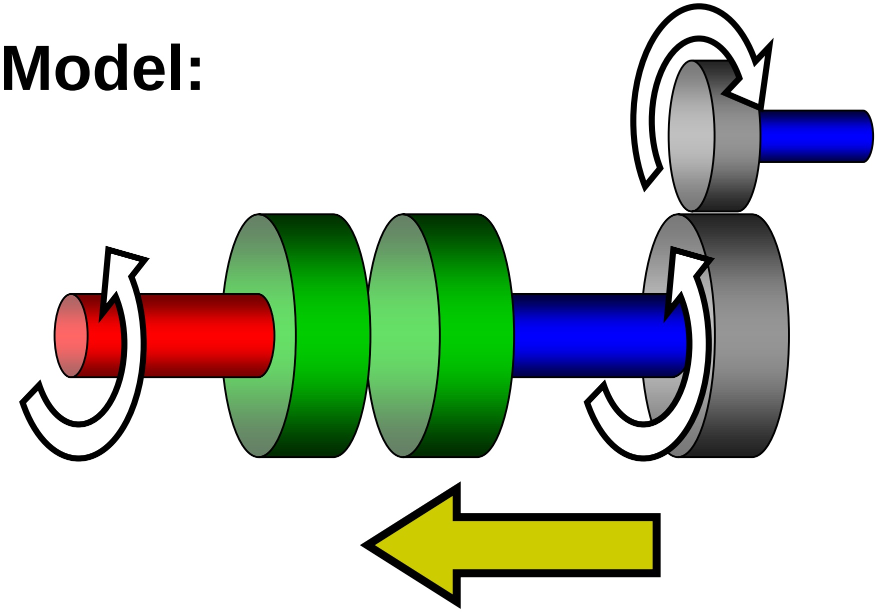
Problem: Simulate the electrical and mechanical components in one environment

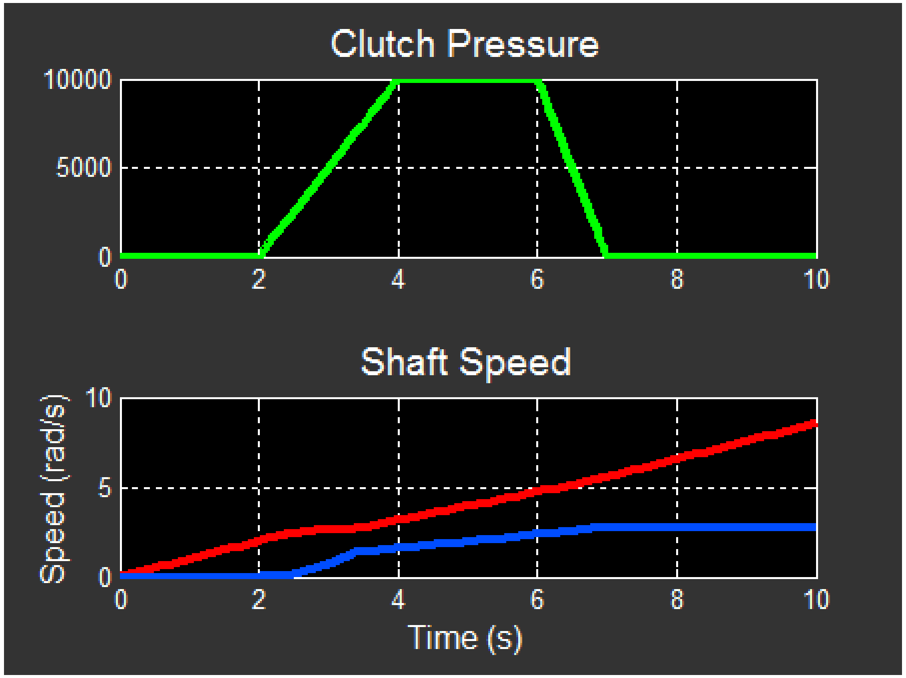
Solution: Use Simscape and SimMechanics to model the system within the Simulink environment



Exercise 3a: Drivetrain with clutch and gear

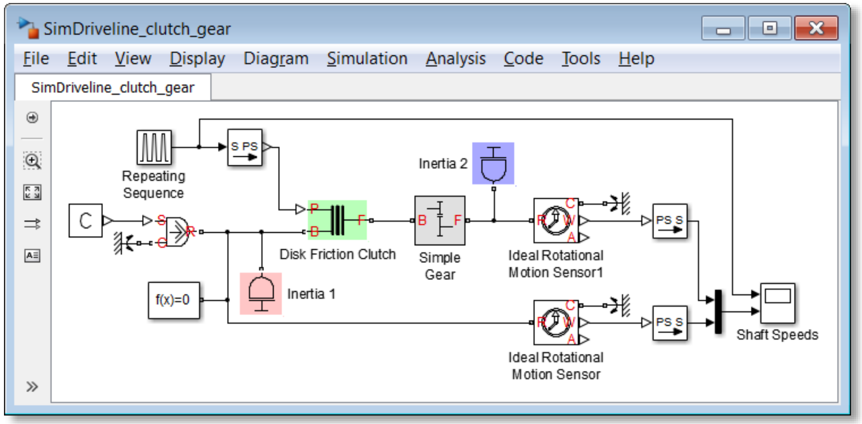
Model:





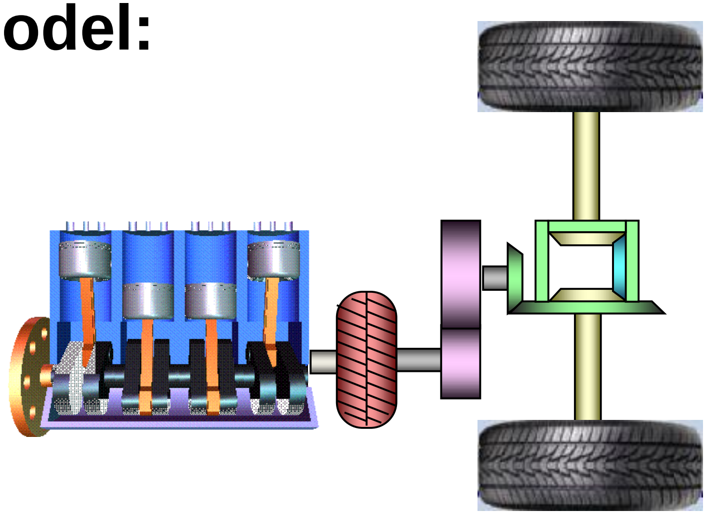
Problem: Model a drivetrain mechanism for use with HIL tests in the Simulink environment.

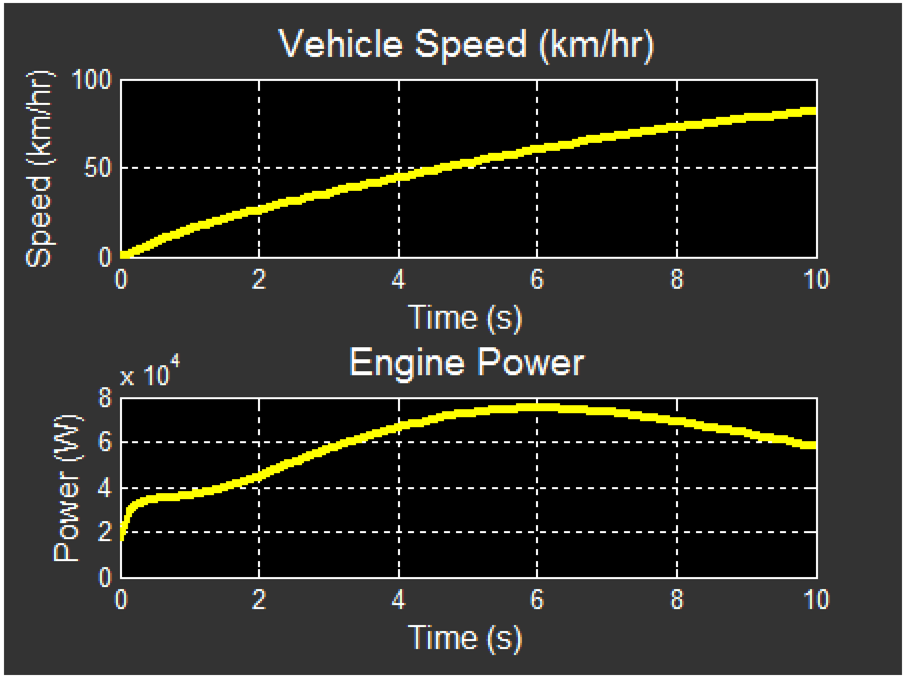
Solution: Use SimDriveline to model the mechanical system.



Exercise 3b: Vehicle Powertrain

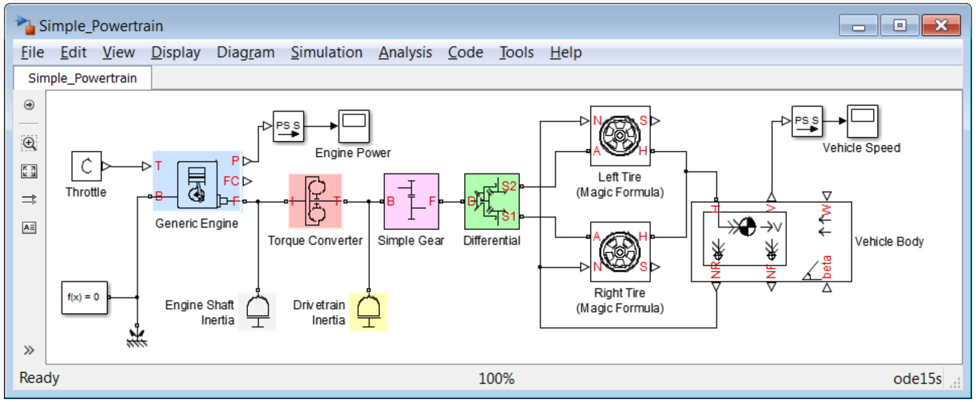
Model:





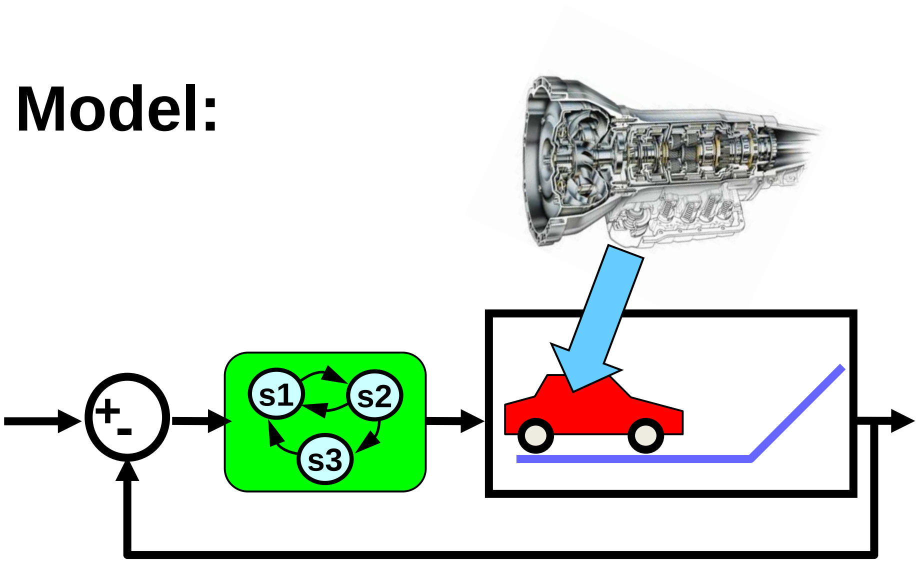
Problem: Create a vehicle drivetrain model that can be reused for controls development

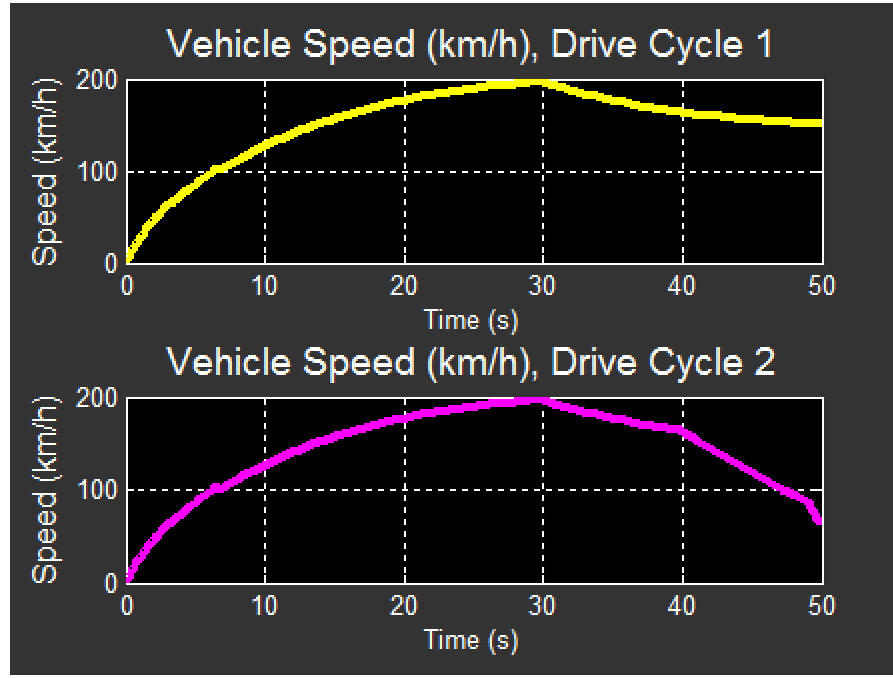
Solution: Use SimDriveline to model the system within the Simulink environment



Exercise 3c: Transmission Controller

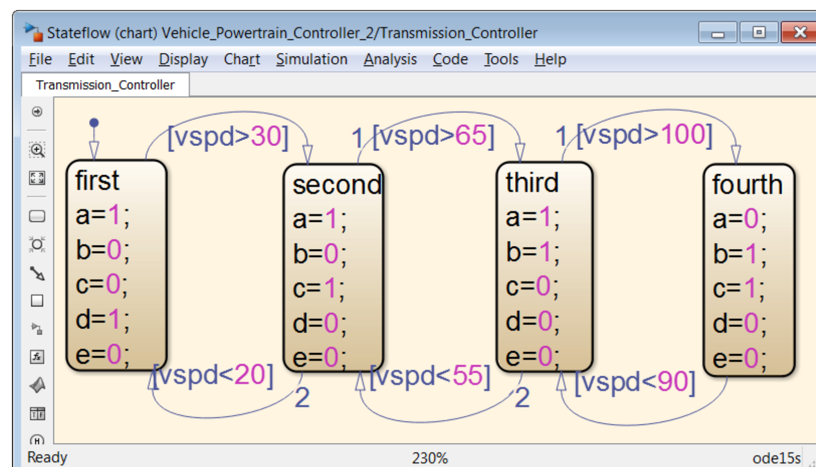
Model:





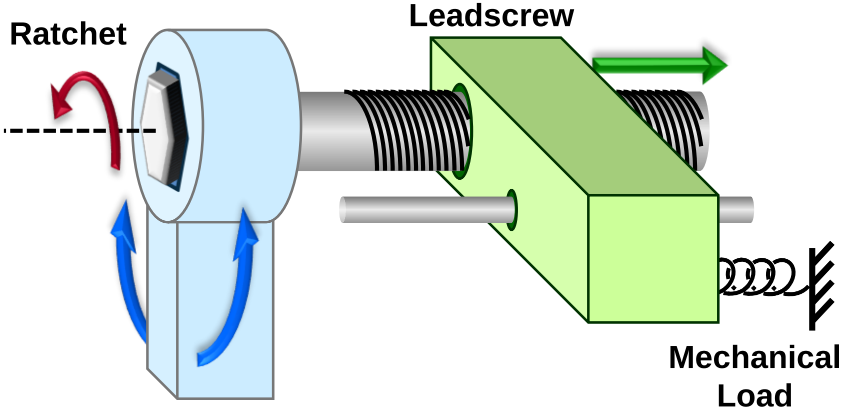
Problem: Add a four-speed transmission and a controller to a powertrain model.

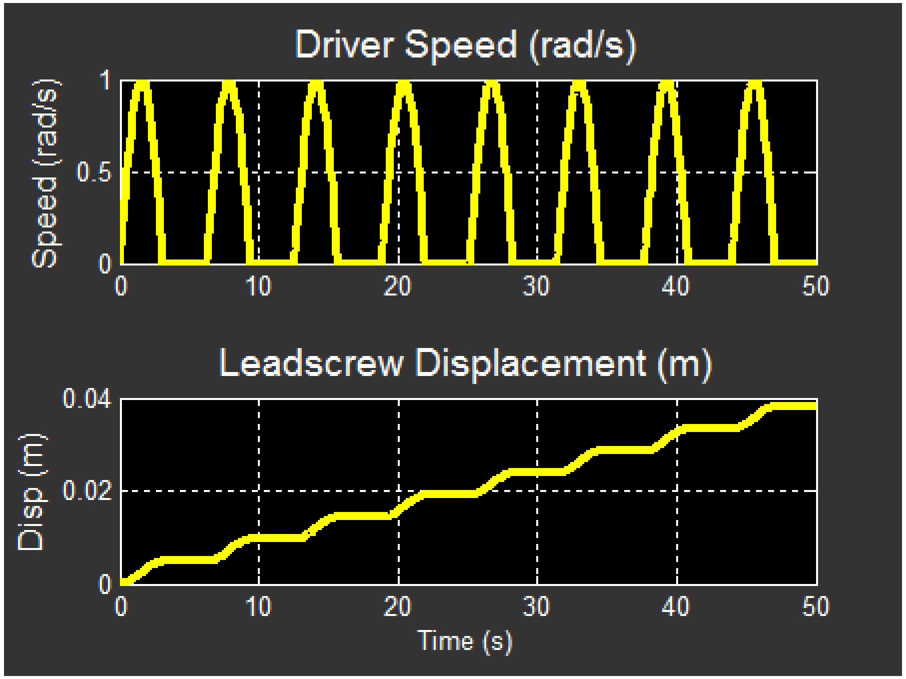
Solution: Use SimDriveline and Stateflow to model the system within the Simulink environment



Exercise 3d: Ratchet Leadscrew Mechanism

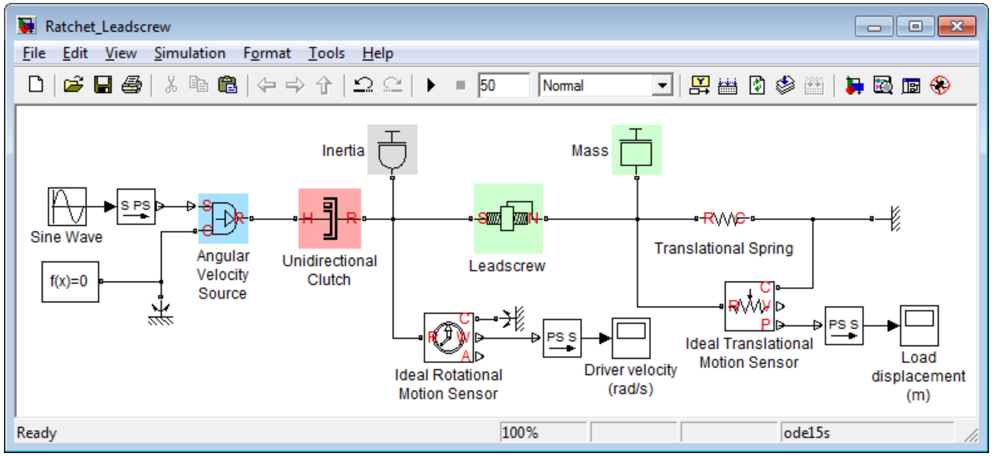
Model:





Problem: Model the ratchet mechanism with self-locking leadscrew

Solution: Use SimDriveline to model the system within the Simulink environment



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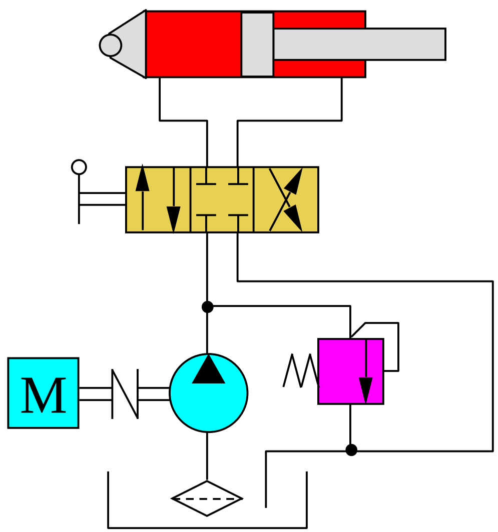
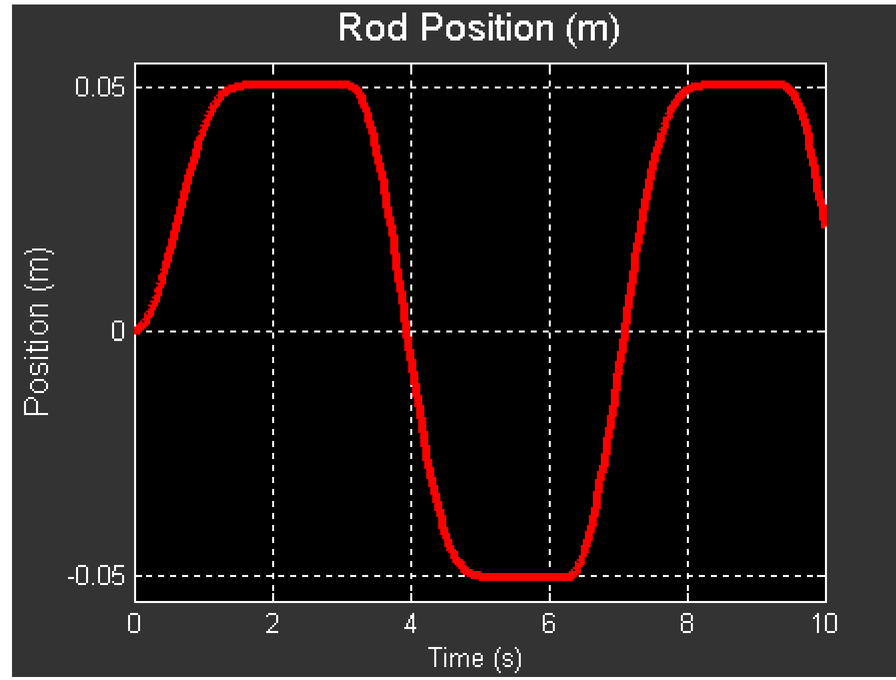
Exercise 4a: Hydraulic Actuation System

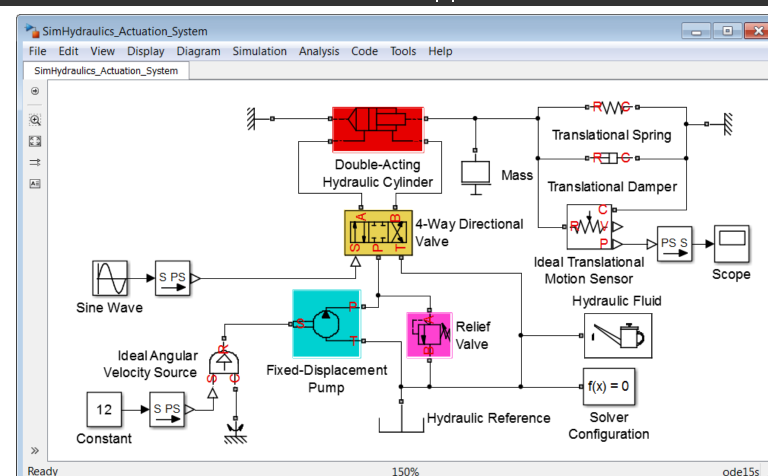
Model:





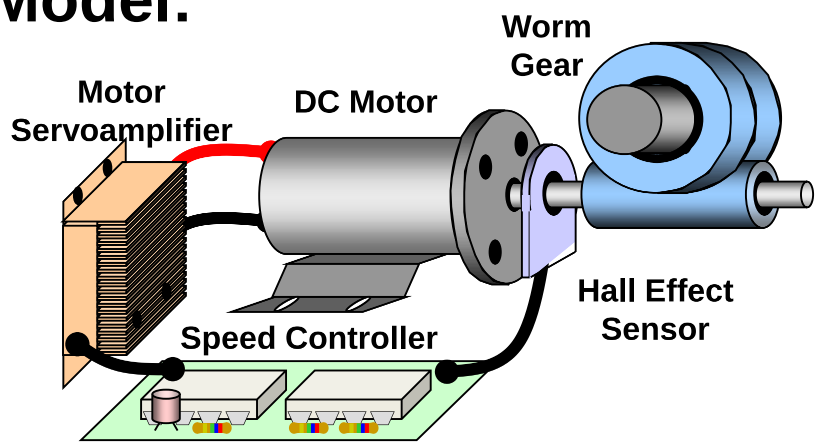
Problem: Model a hydraulic actuation system within the Simulink environment

Solution: Use [SimHydraulics](#) to model the hydraulic actuation system

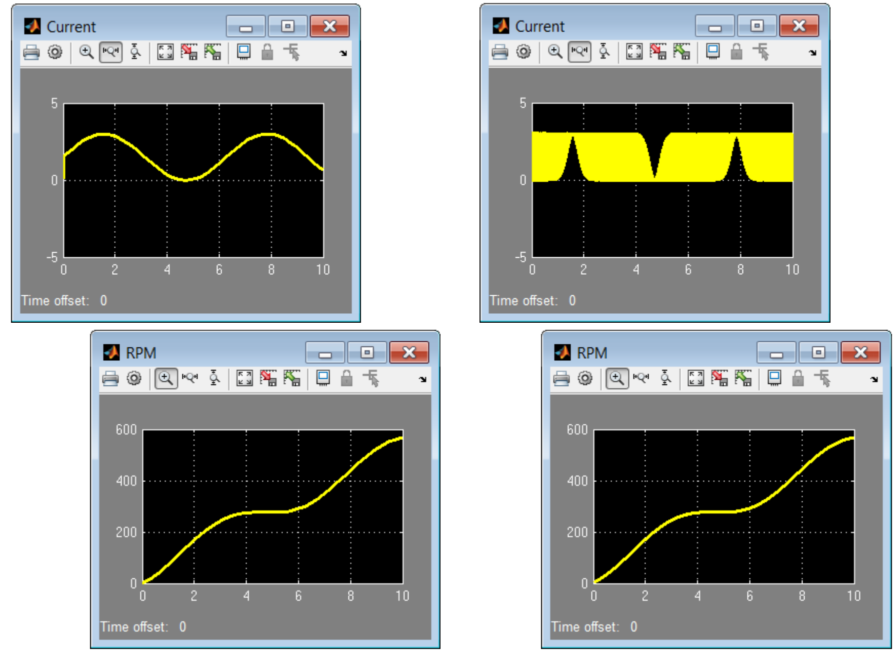


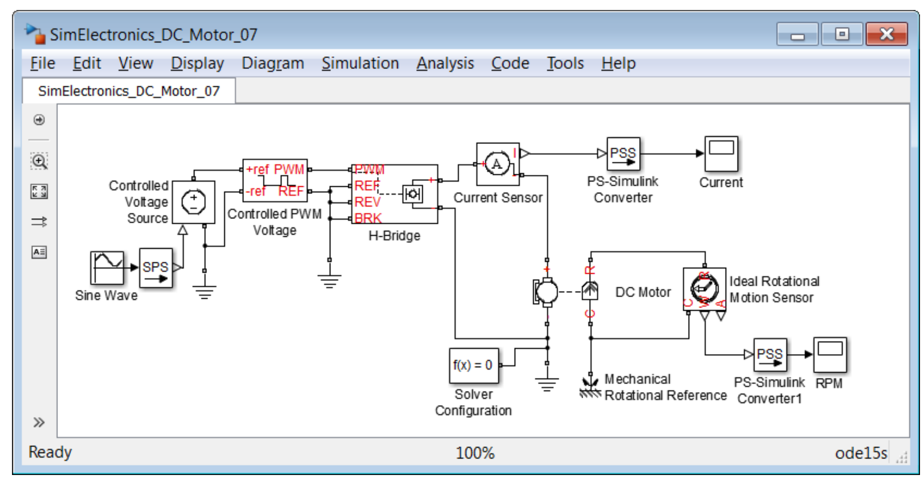
Exercise 5a: Linear Actuator with DC Motor

Model:



Averaged Mode **PWM Mode**





Problem: Model a closed-loop position control system with a DC motor driving a linear actuator

Solution: Use Simscape, SimElectronics and Simulink to model the electromechanical control system

Exercise 6a: PWM Controlled Motor

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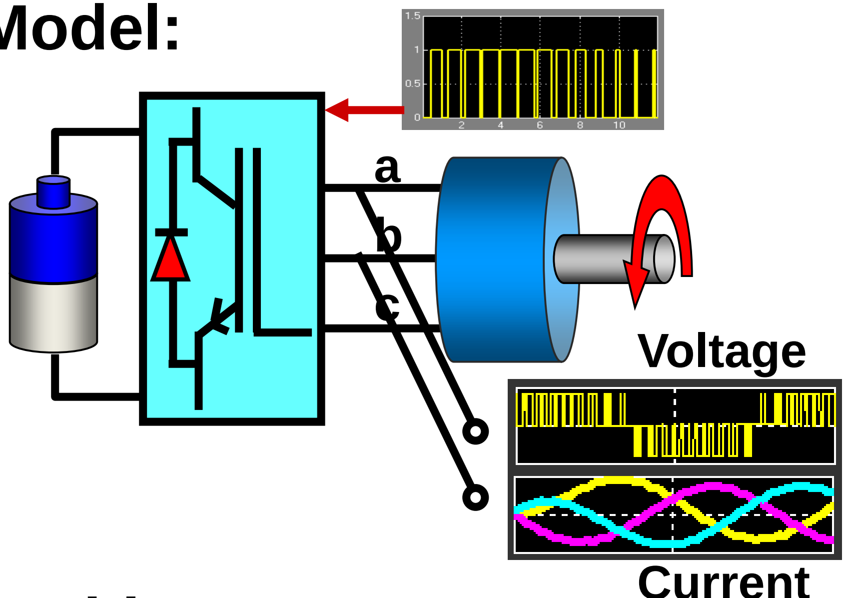
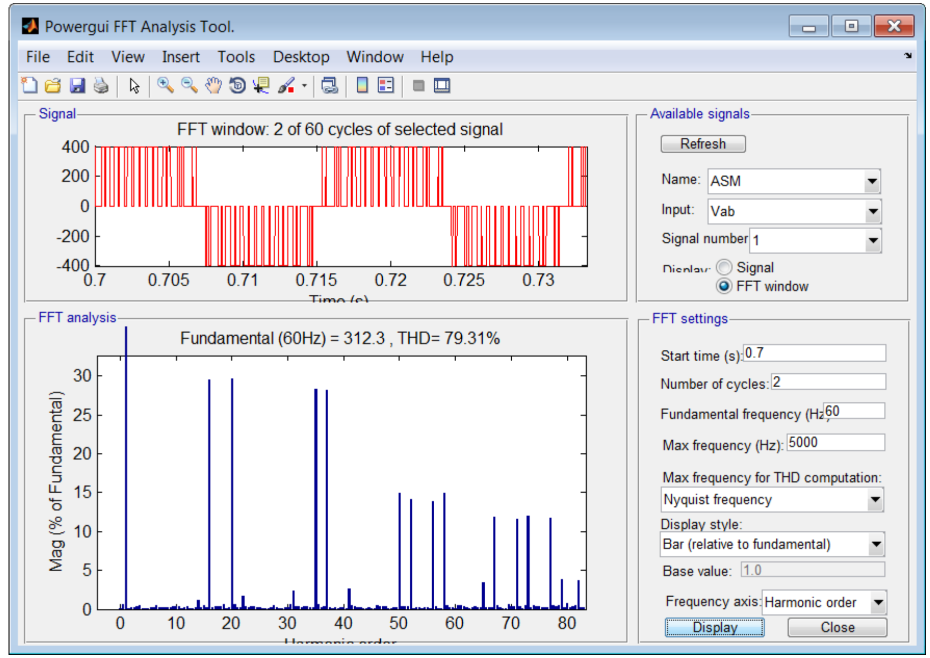
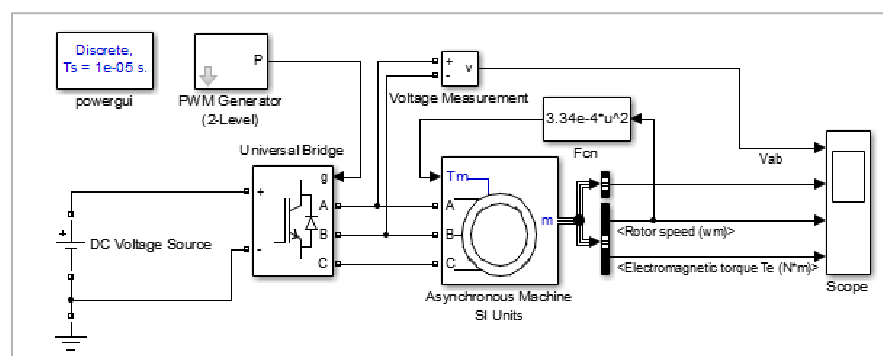
Model:





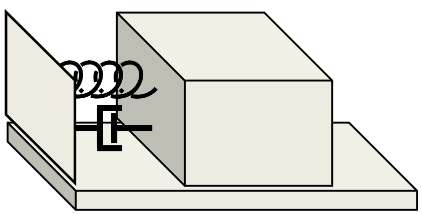
Problem: Determine the frequency spectrum of the phase-to-phase voltage of the motor.

Solution: Use [SimPowerSystems](#) and the PowerGUI to determine the frequency spectrum.



Exercise 7a: Custom Mechanical Springs

Model:



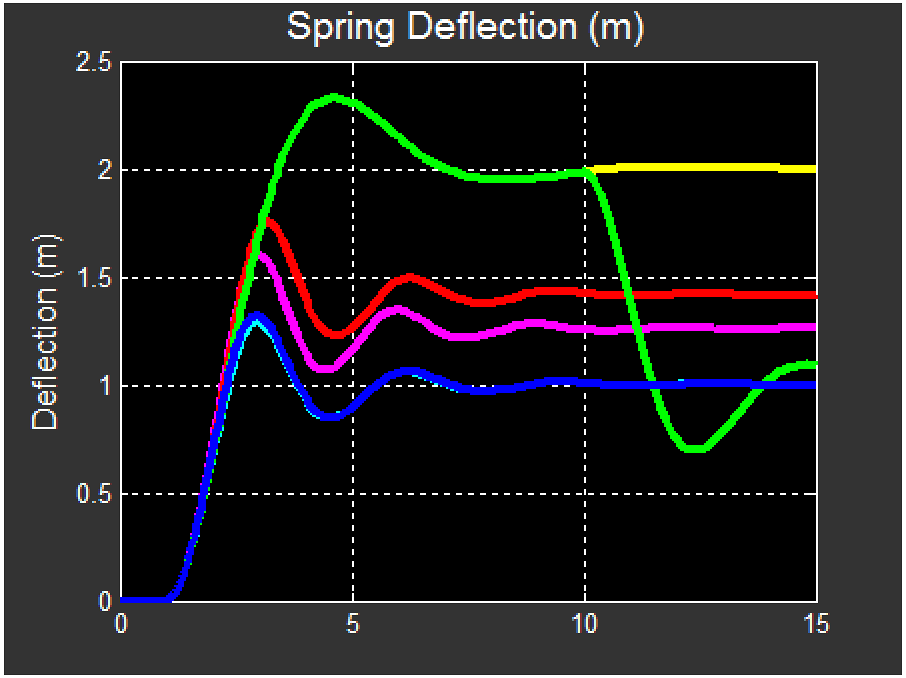
$F = k*x$

$F = k*x^3$

$F = k*x + k_1*x^3$

$$F = \begin{cases} k*x & x < x_c \\ k_1*x^3 & x >= x_c \end{cases}$$

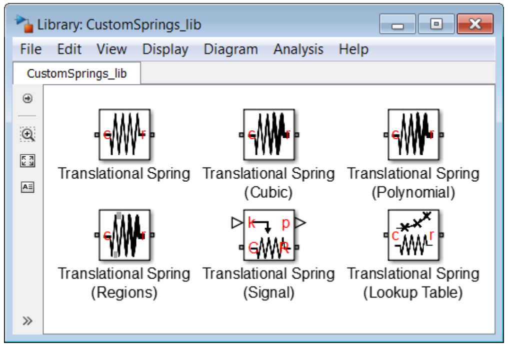
$F = (\text{lookup table})*x$



Problem: Create models of custom mechanical springs within the Simulink environment

Solution: Use the Simscape language to define reusable spring models

```
equations
  f == k*x^3;
  v == x.der;
end
```



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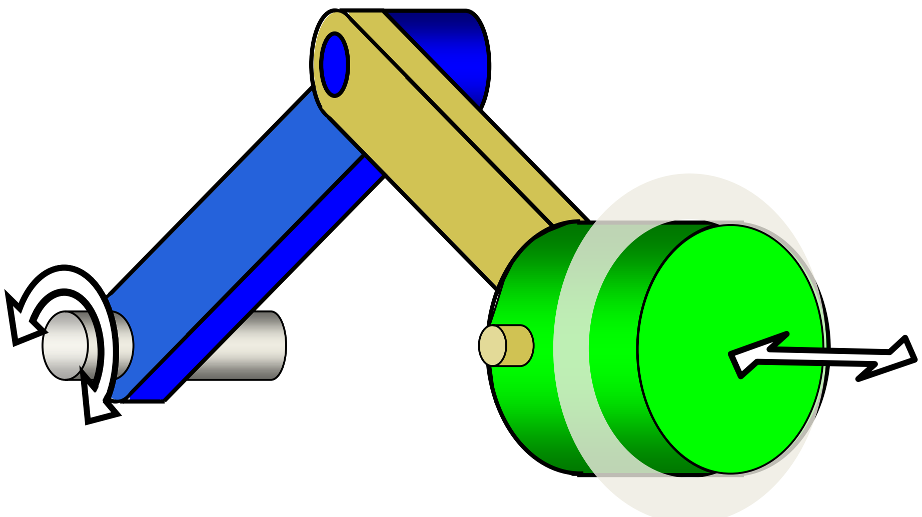
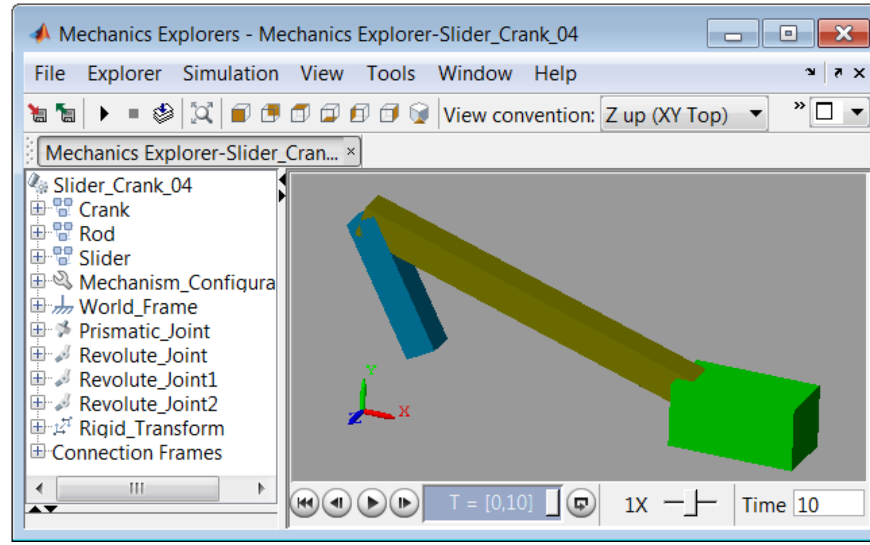
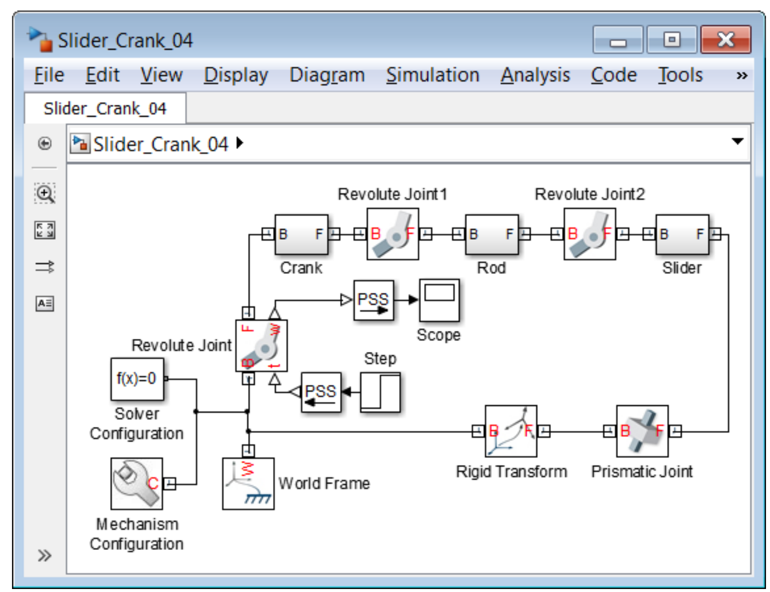
Exercise 8a: Slider Crank

Model:







Problem: Model a piston using reusable component models in the Simulink environment.

Solution: Use SimMechanics to model the mechanical system.