TeraSoft
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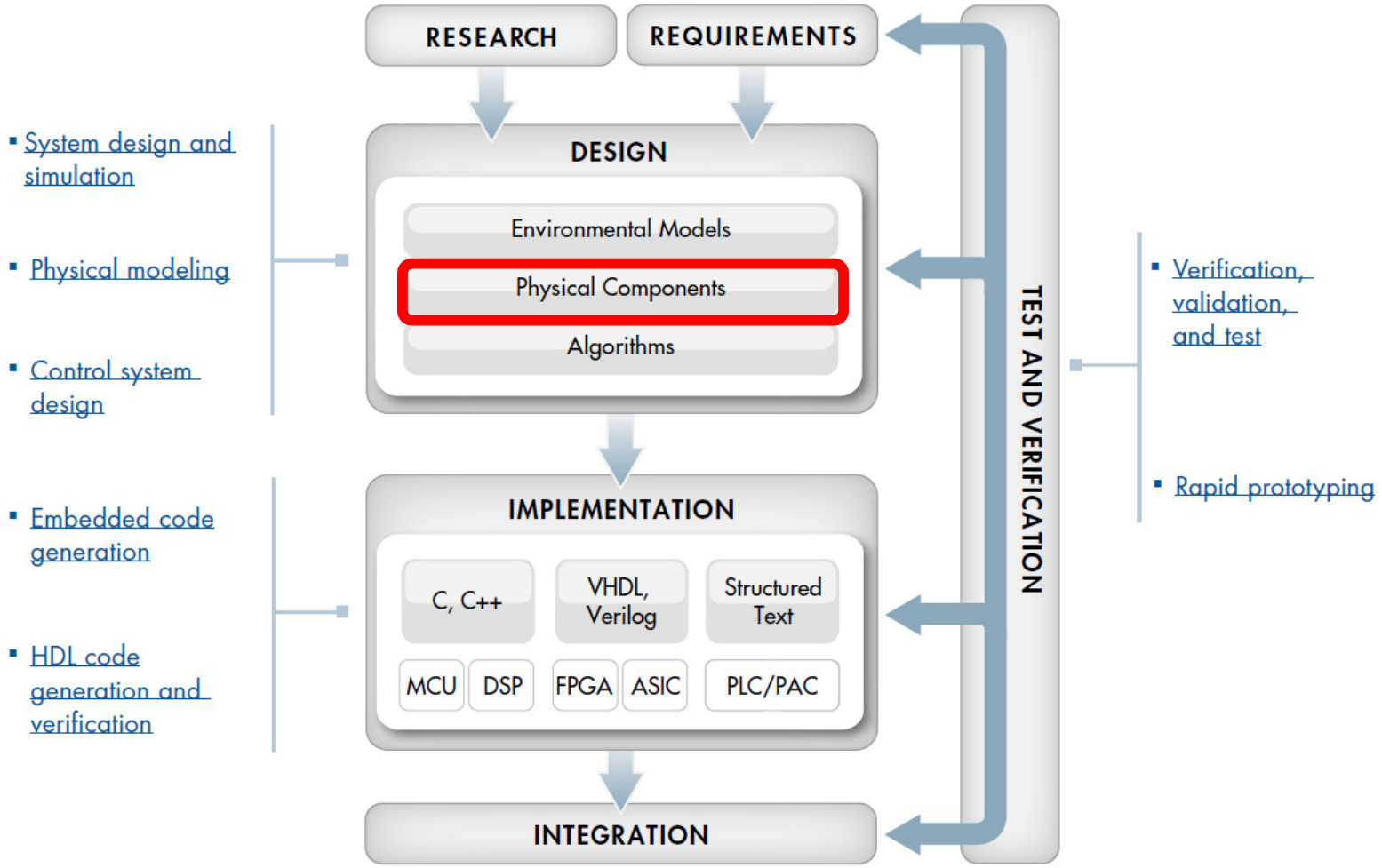
Using Simulink for Dynamic System Modeling

Workflow for Model-Based Design



Agenda

- What's new in Simscape Family
- Building Dynamic model with Simscape
  - Foundation library
  - Simscape language
  - Estimate Model Parameter Values
- Simscape Multibody
  - Multibody introduction
  - Import from CAD

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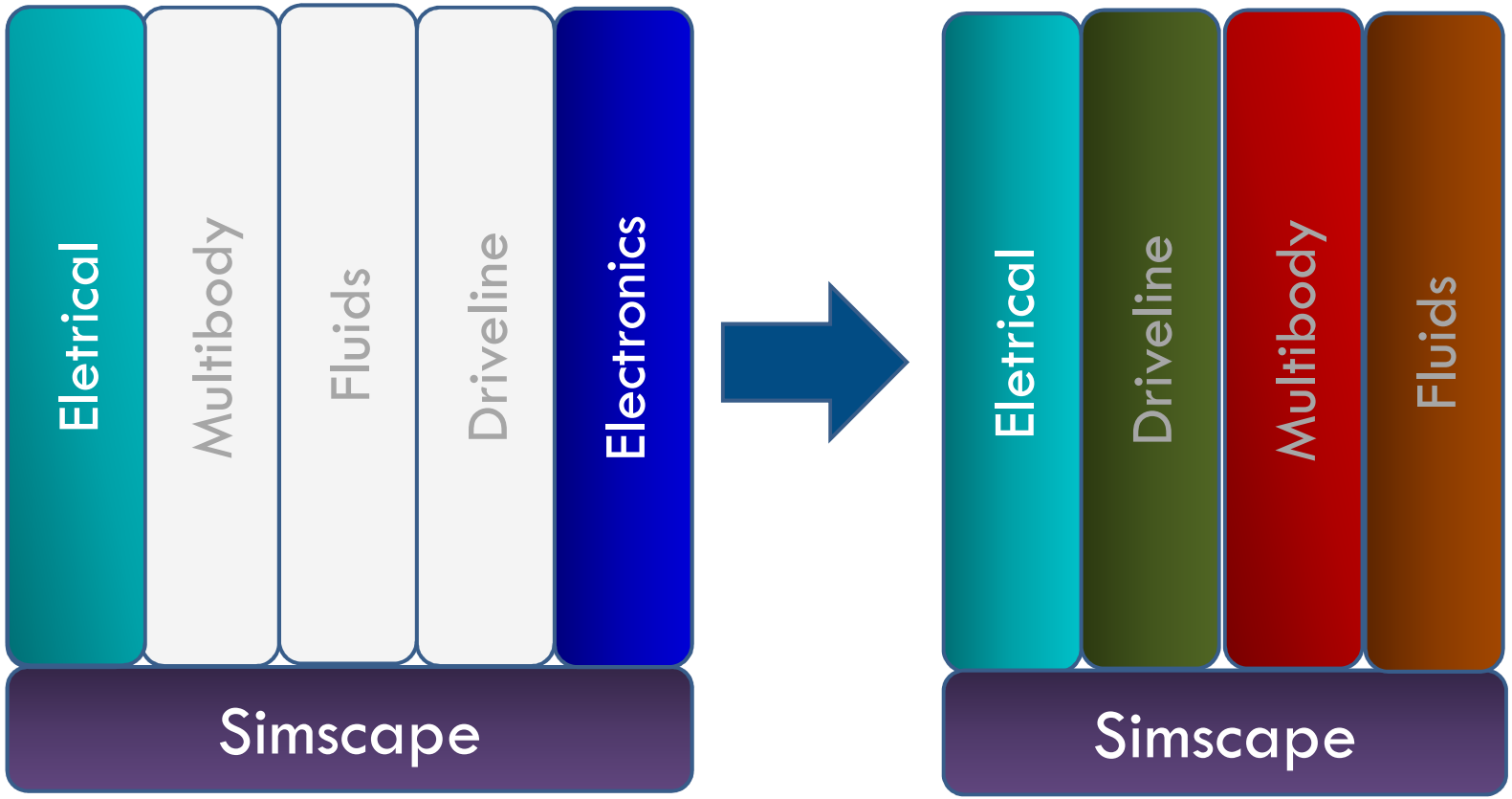
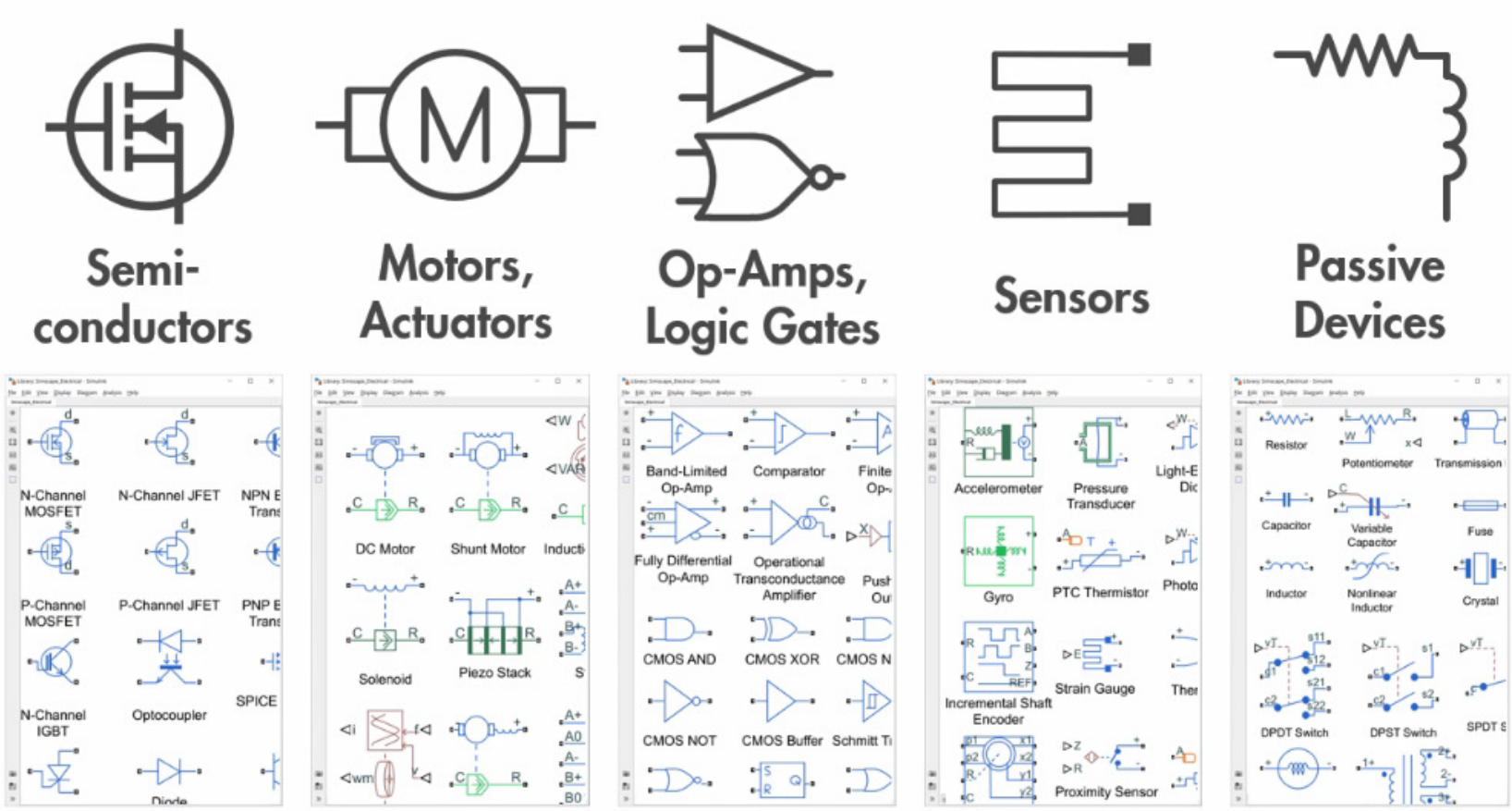
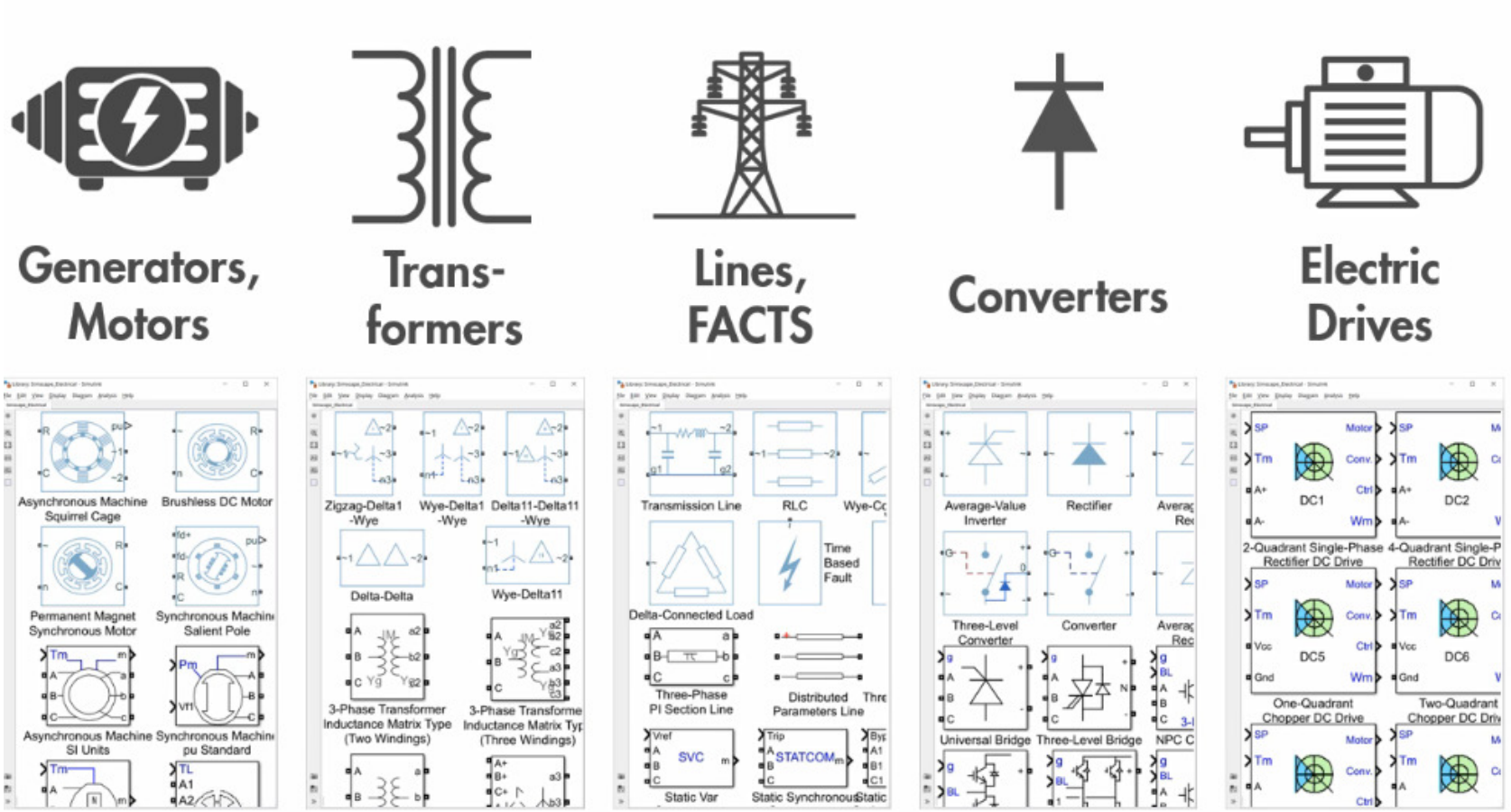
New Simscape Family



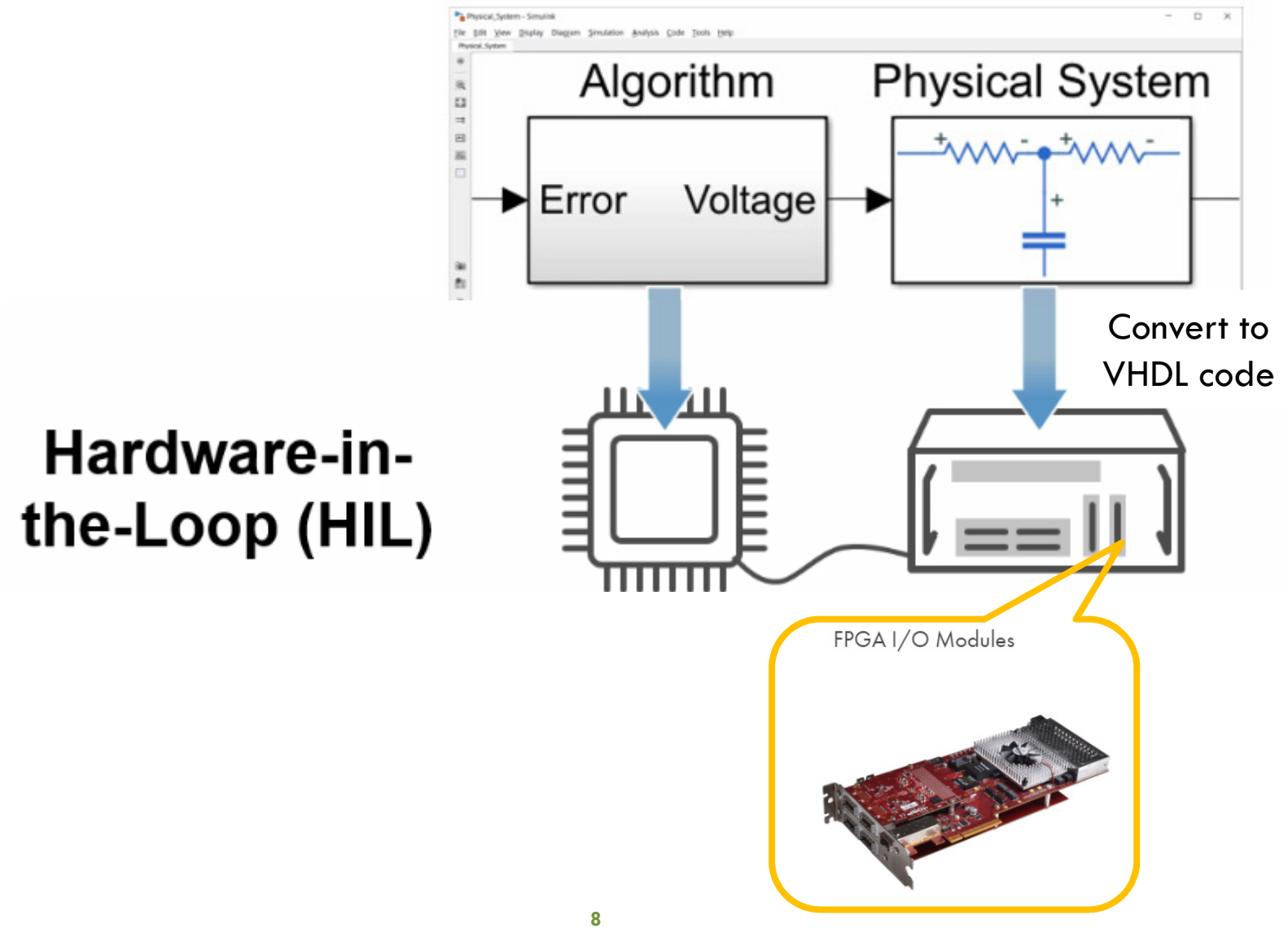
Simscape Electrical



Simscape Electrical



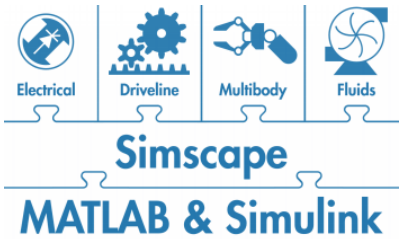
Support HDL code generation



Simscape on FPGA

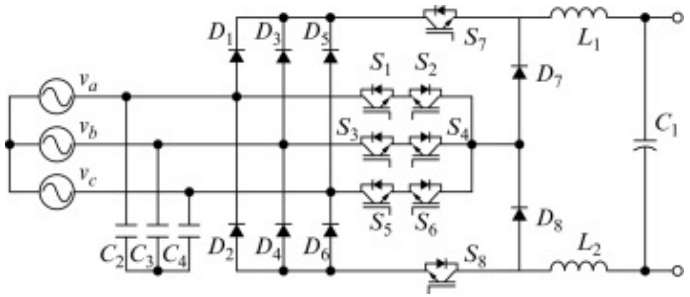
Simscape

- Modelling of physical system within Simulink (e.g. power electronics, electric motors, sensors, actuators, …)
- Simulate and test **controller and plant seamlessly** including the physical system



Requirements

- Demanding sample time requirements (<1us)
- Lowest latency
- Floating point support

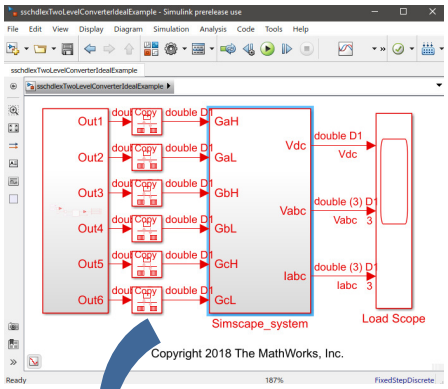


Swiss rectifier (three-phase buck-type PFC)

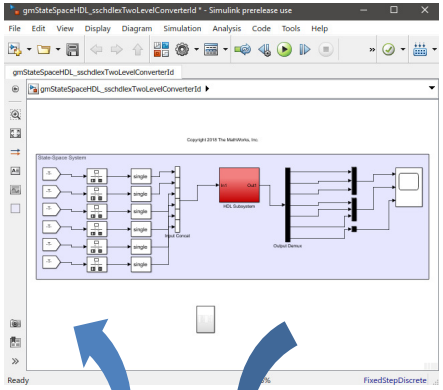
Simscape on FPGA

R2018b

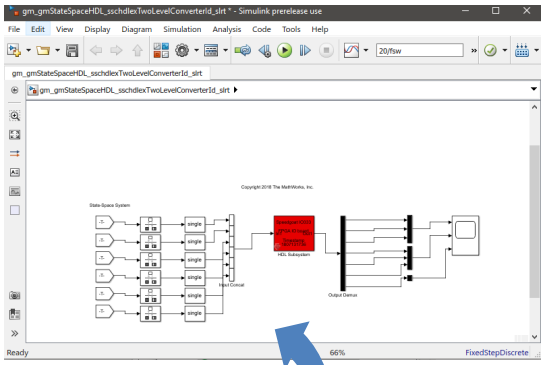
Simscape model

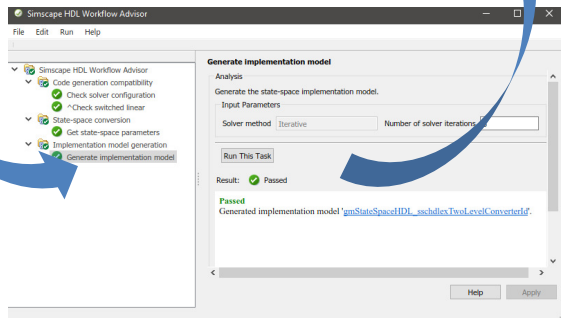


Simulink state-space model

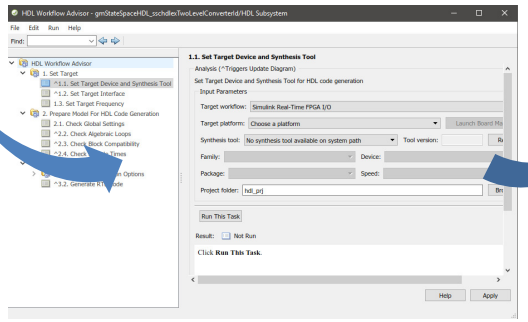


Generated model





Simscape HDL Workflow Advisor



HDL Workflow Advisor

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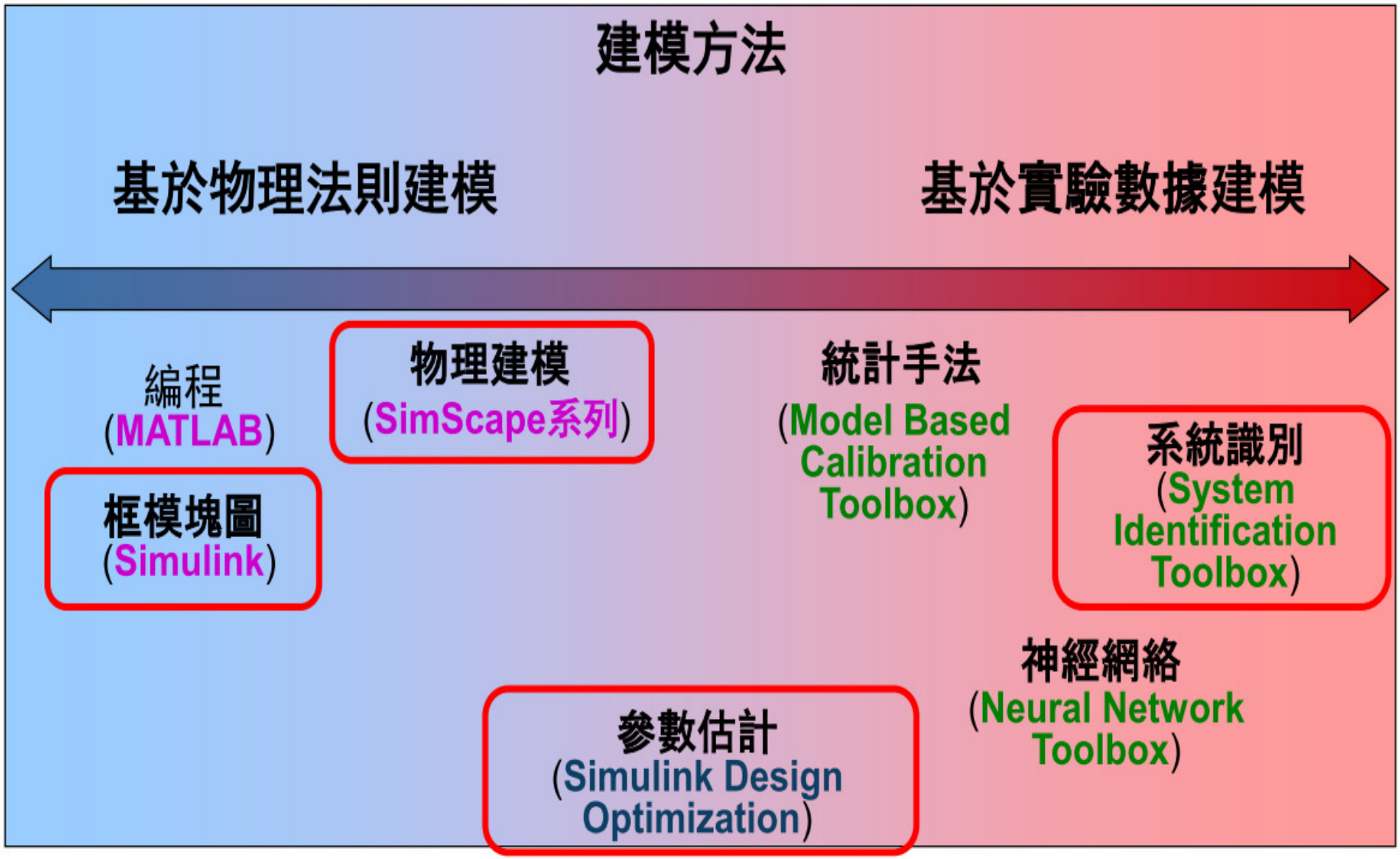
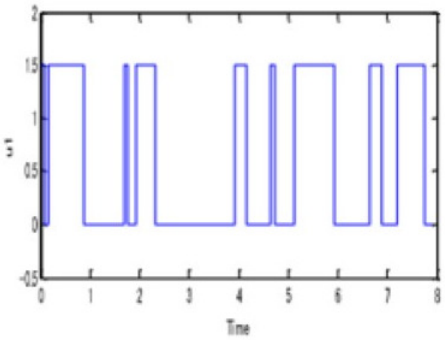


例題:對直流電機建模



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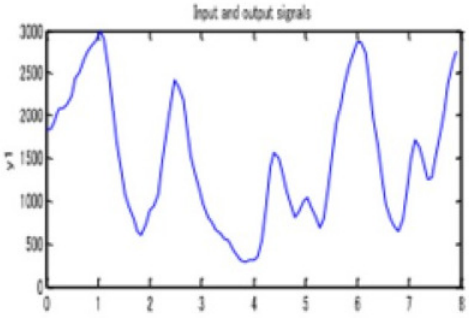

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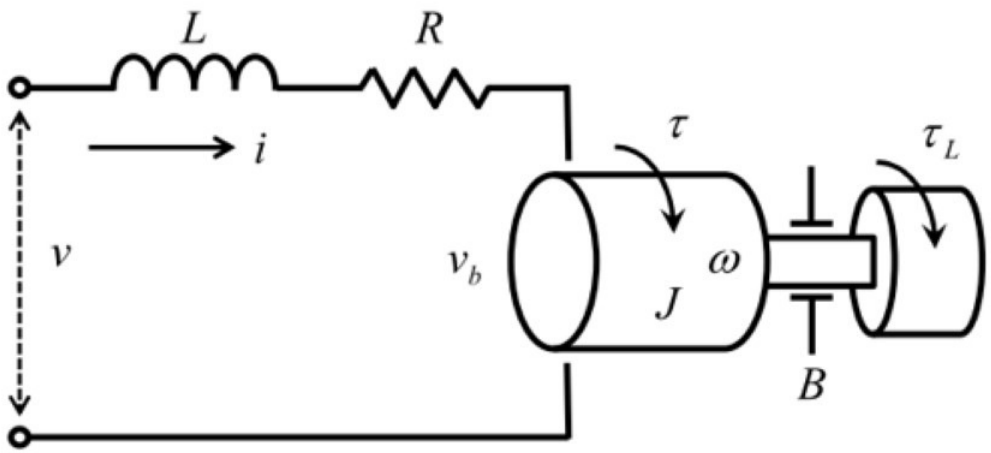
速度

直流電機的數學模型



$$v_m(t) = v(t) - v_b(t)$$

參數	物理量
$L[H]$	電樞電感
$R[\Omega]$	電樞抵抗
$K[V/(rad/s)]$	反電動勢常數
$J[kg*m^2]$	轉子轉動慣量
$B[N*m/(rad/s)]$	轉子的動態摩擦係數
$\tau_L[N*m]$	負載轉矩

機械系

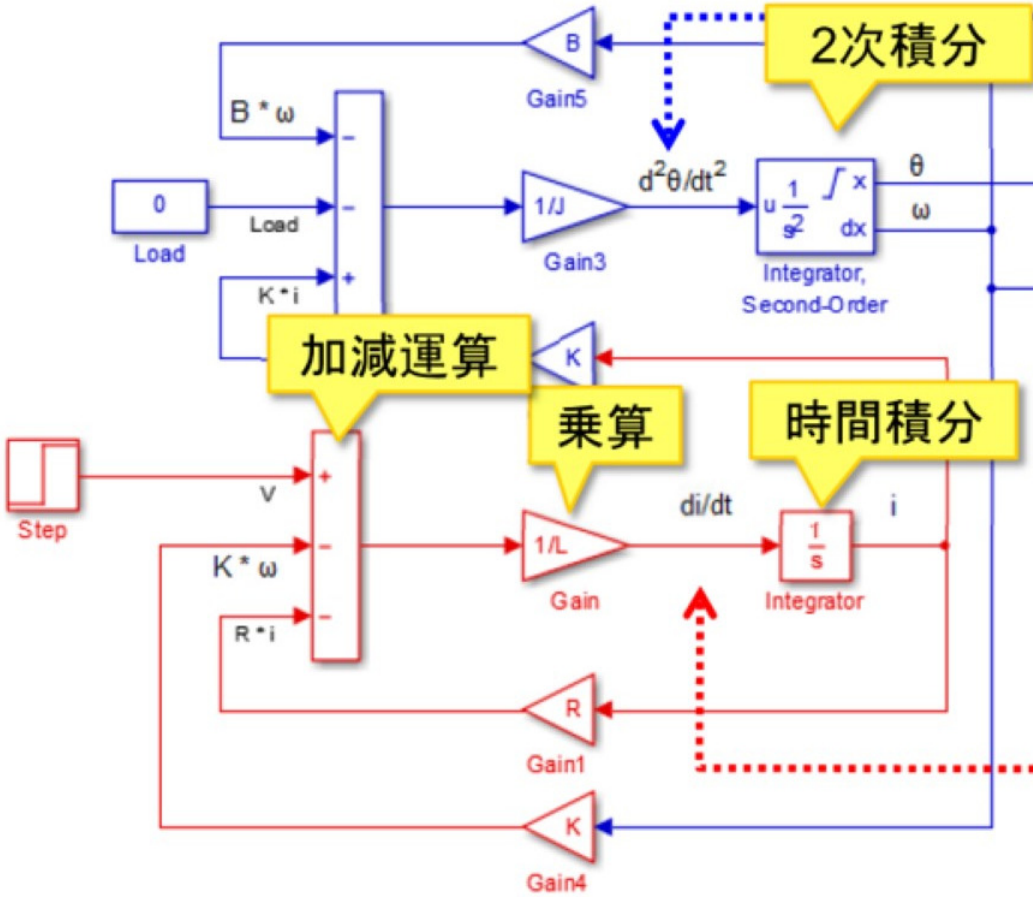
$$J\frac{d\omega(t)}{dt} + B\omega(t) + \tau_L(t) = \tau(t) \qquad \tau(t) = Ki(t) \qquad \omega(t) = d\theta(t)/dt$$

電気系

$$L\frac{di(t)}{dt} + Ri(t) + v_b(t) = v(t) \qquad v_b(t) = K\omega(t)$$

使用Simulink建立直流電機的数學模型

使用模塊圖來表現運動方程式/電路方程式



$$\frac{d^2\theta}{dt^2} = \frac{1}{J}\left(Ki - B\omega - \tau_L\right)$$

機械系

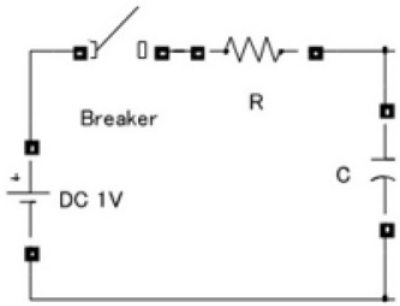
電気系

$$\frac{di}{dt} = \frac{1}{L}\left(v - Ri - K\omega\right)$$

什麼是基於物理元件的建模?

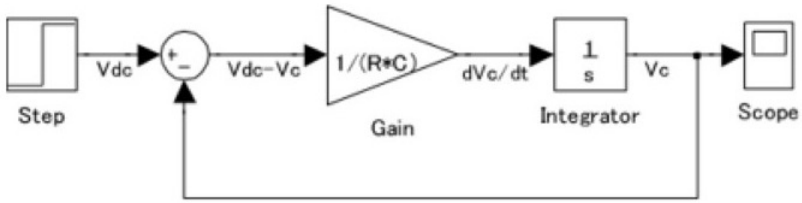
RC串聯電路

物理建模



Simulink

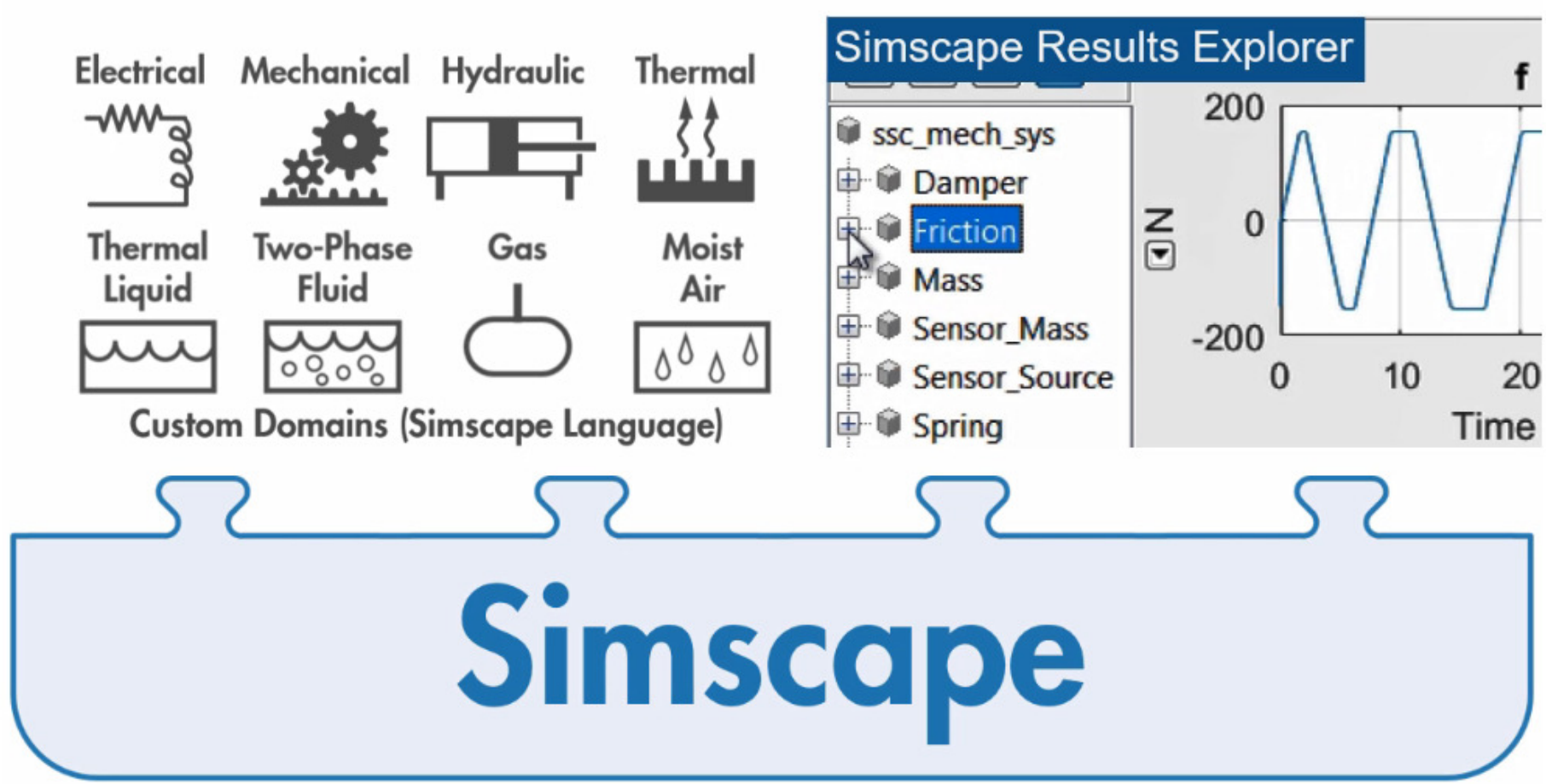
$$\frac{dV_c}{dt} = \frac{1}{RC}\left(V_{dc} - V_c\right)$$



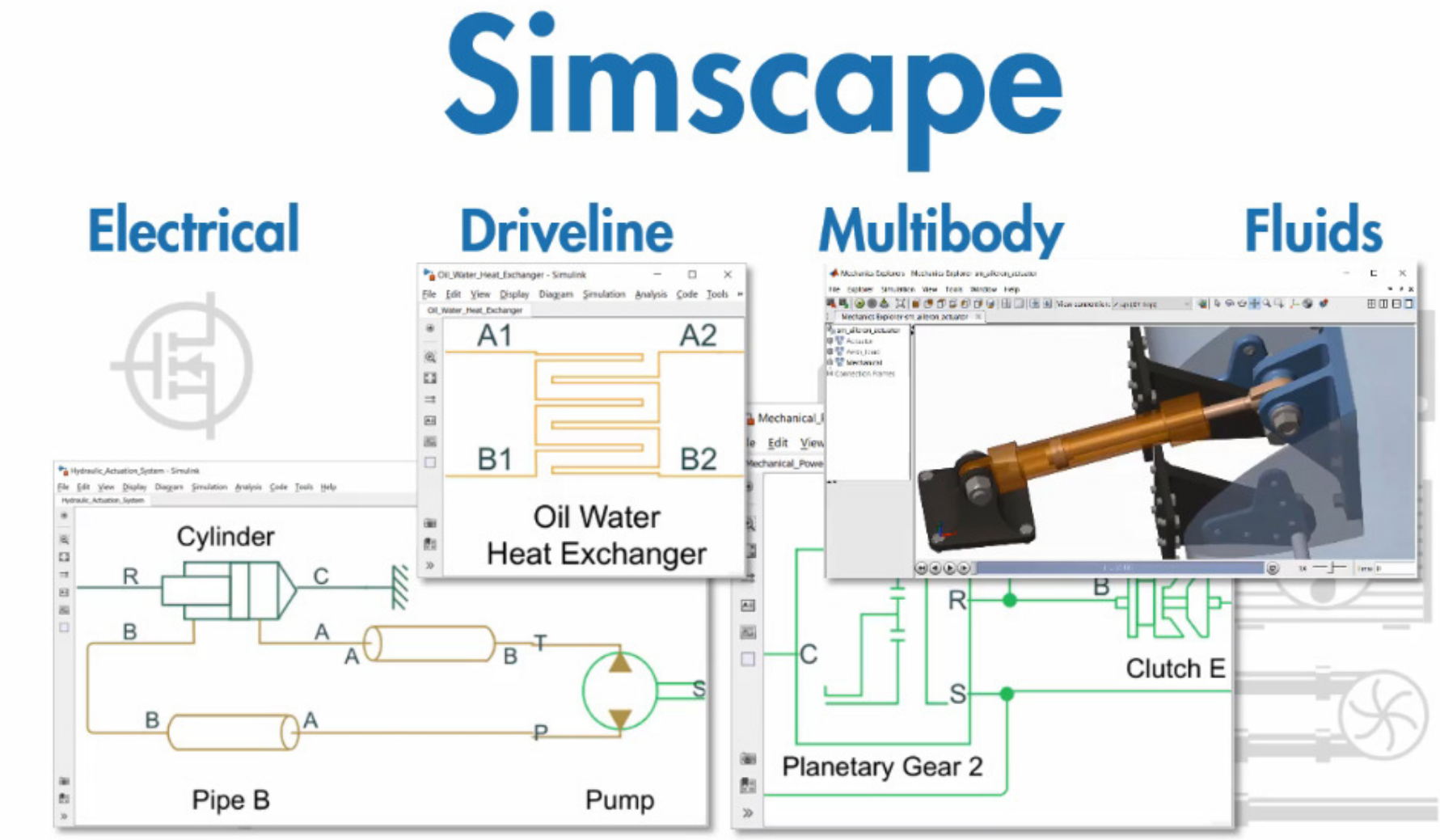
Physical Modeling

- Model matches structure of system
- Physical connections
- Equations handled automatically by Simscape
- Generate C/VHDL code from Plant model for HIL

Simscape Foundation library

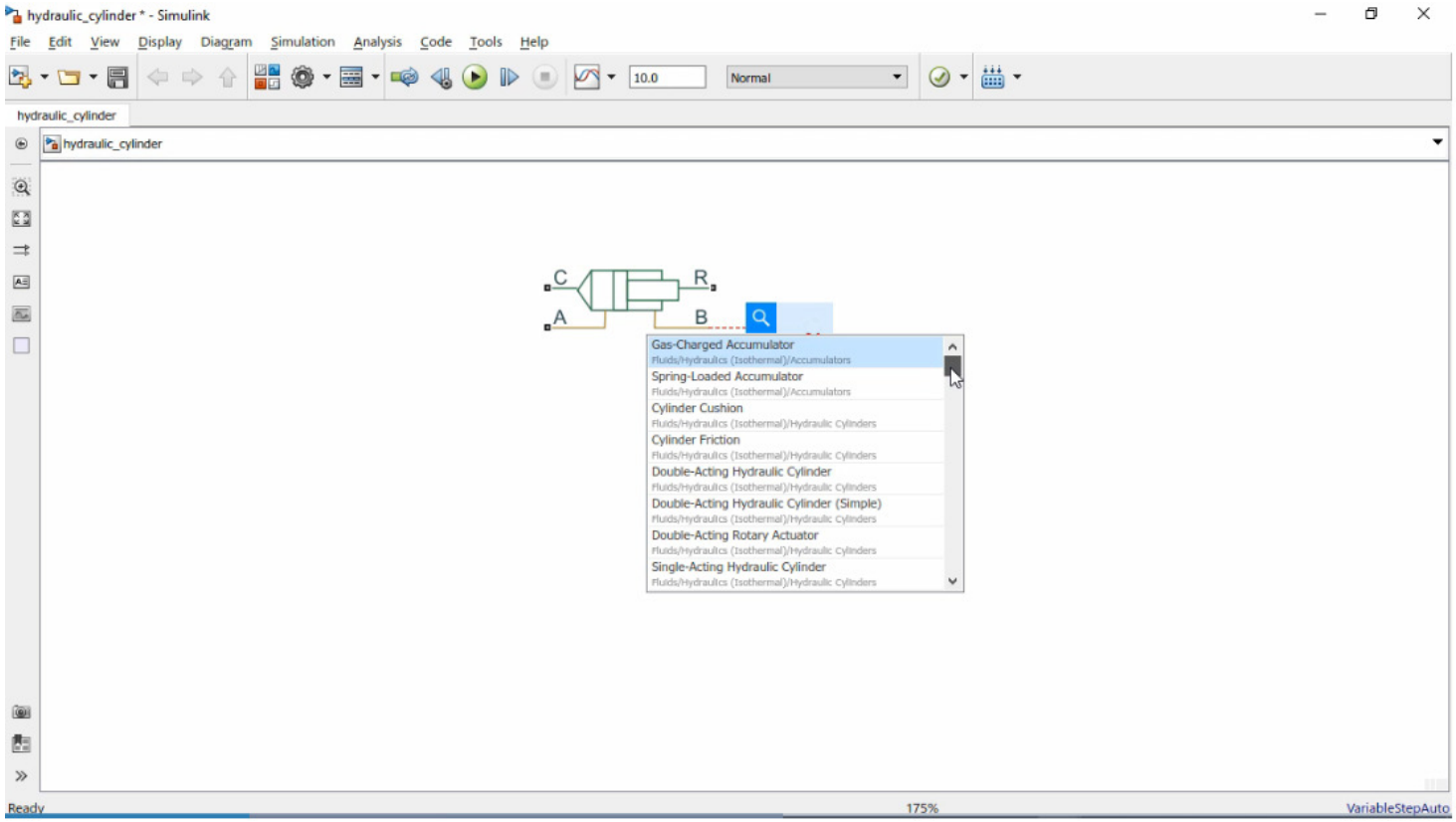


Multi-domain modeling



How to start Simscape ?

- Use command >>ssc_new
- Use Predictive Quick Insert



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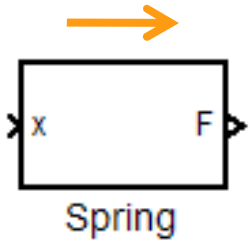
Extending Simscape™ Models

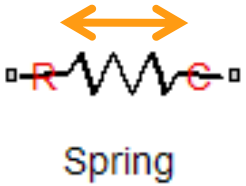
Using Simulink® blocks



F = k*x

- Physical variables explicitly calculated
- Sensors and sources used to integrate with Simscape blocks

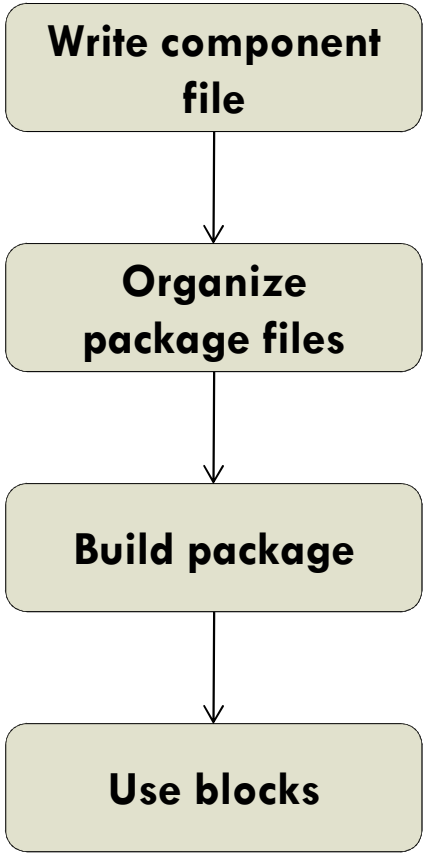
Using Simscape language

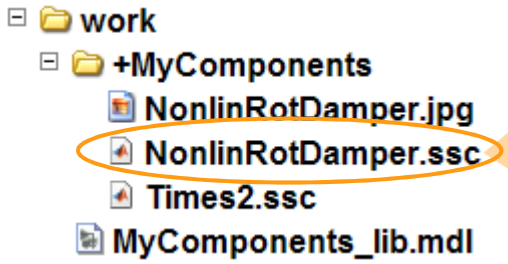


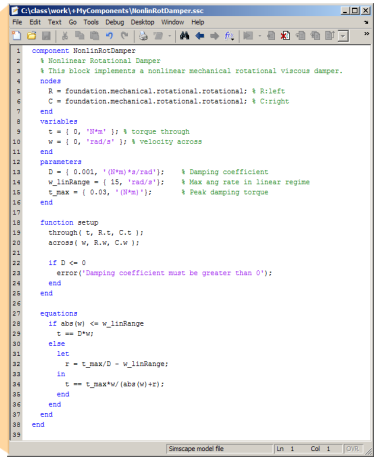
F == k*x

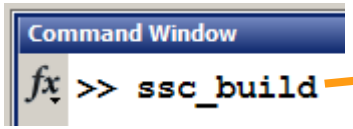
- Physical variables specified using equivalence relationship
- Integrates seamlessly with other Simscape blocks

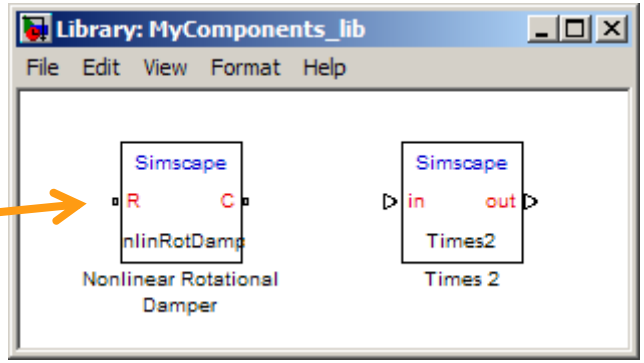
Simscape™ Language and Packages



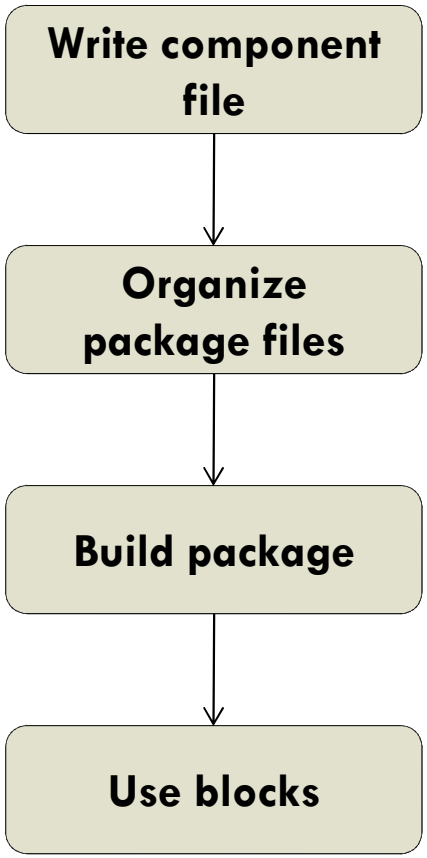








Example: Times2 Component



C:\class\work\+MyComponents\Times2.ssc

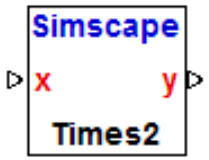
File Edit Text Go Tools Debug Desktop Window Help

```
1   component Times2
2       % Times 2
3       % This component outputs twice
4       % the value of the input.
5
6       inputs
7           x = 0; %in
8       end
9       outputs
10          y = 0; %out
11      end
12
13      equations
14          y == 2*x;
15      end
16  end
17
```

Simscape model file

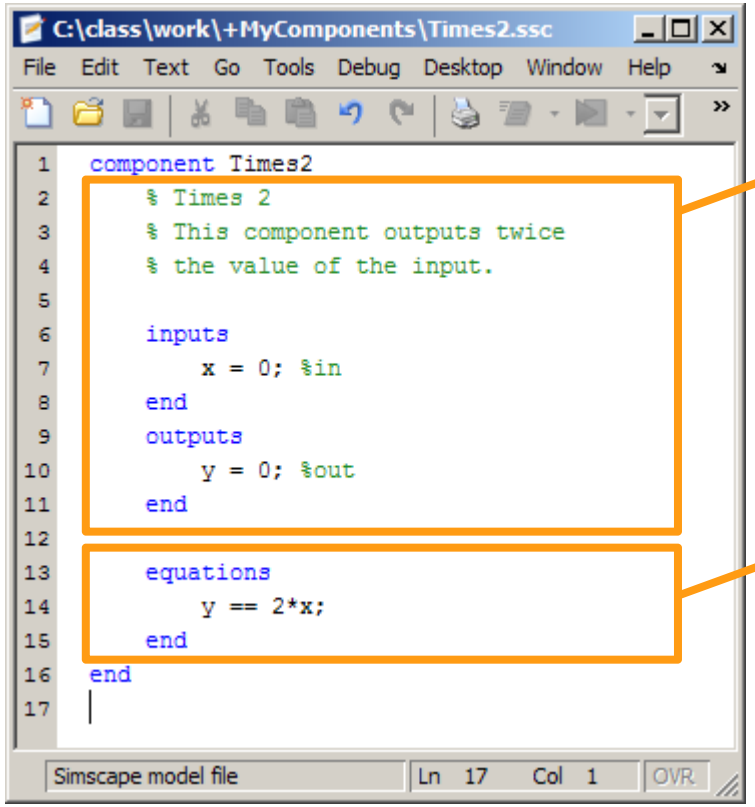
Library: MyCustomComponents_lib

File Edit View Format Help



Times2

Example: Times2 Component (Continued)



Declaration section

Defines ports, variables, and user interface

Equations section

Establishes the mathematical relationship between variables, parameters, inputs and outputs

== is a equality operator,
not an assignment operator

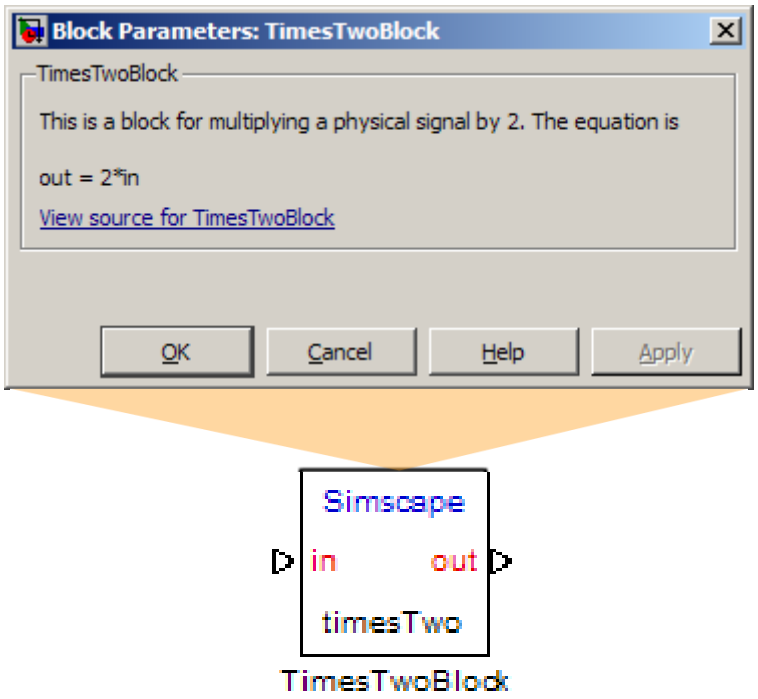
Port Labels and Documentation

```
component timesTwo
    %TimesTwoBlock
    %
    %This is a block for multiplying
    %a physical signal by 2.
    %
    %The equation is
    %
    %out = 2*in

    inputs
       x = 0; %in
    end

    outputs
        y = 0; %out
    end

    equations
        y == 2*x;
    end
end
```



Component Model File Overview

Declaration

inputs

outputs

nodes

parameters

variables

Defines block interface and variables

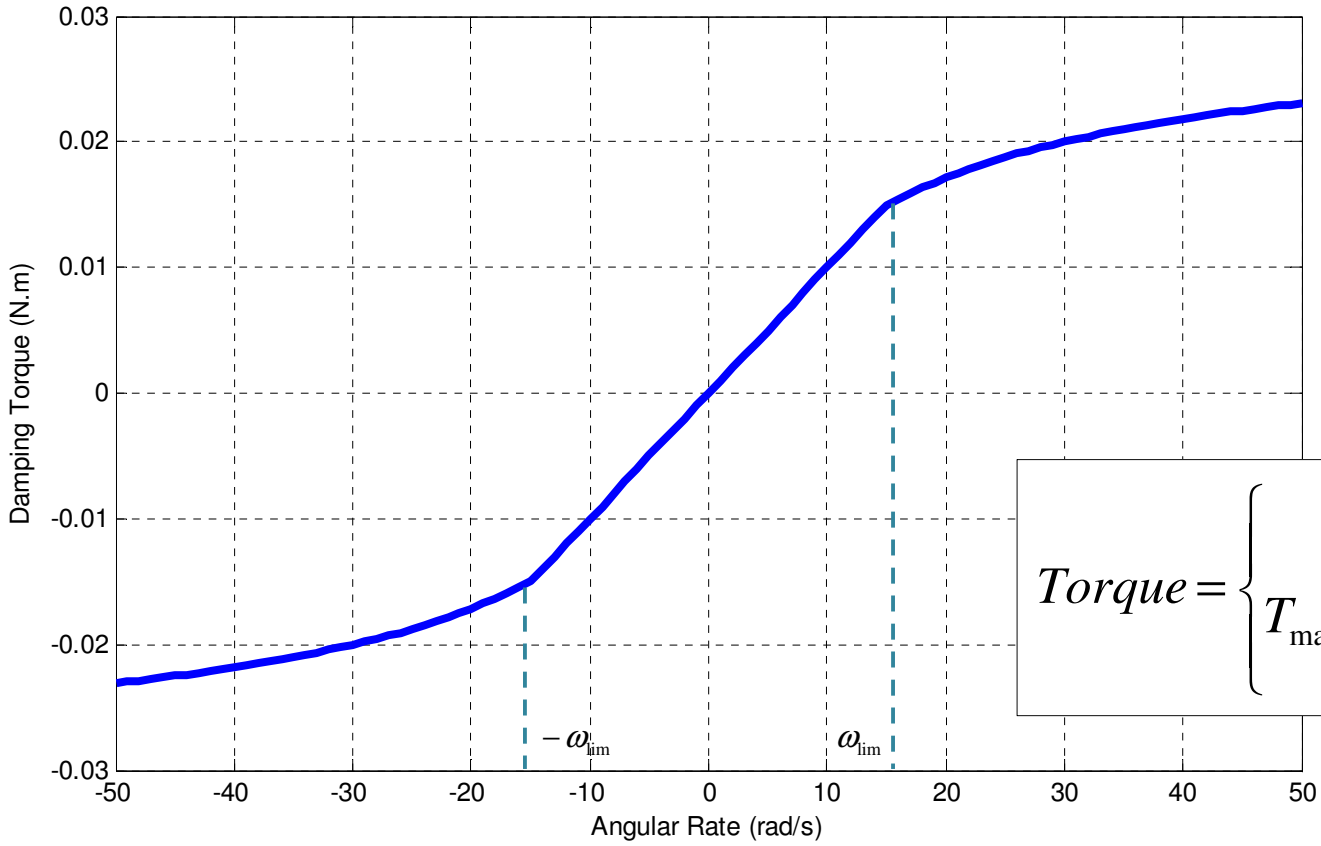
setup

Check parameters, set initial conditions

equations

Defines physical equations to be used during simulation.

Example: Nonlinear Rotation Damper



$$Torque = \begin{cases} D \cdot \omega & |\omega| \le \omega_{lim} \\ T_{max} \cdot \dfrac{\omega}{|\omega| + r} & |\omega| > \omega_{lim} \end{cases}$$

where $r = \dfrac{T_{max}}{D} - \omega_{lim}$

Declaration Section

Declaration

- Create nodes that reference physical domains
- Instantiate Through and Across variables and/or declare internal variables
- Specify tunable parameters, their default values and units

$$Torque = \begin{cases} D \cdot \omega & |\omega| \le \omega_{lim} \\ T_{max} \cdot \dfrac{\omega}{|\omega| + r} & |\omega| > \omega_{lim} \end{cases}$$

Nodes — Two rotational nodes

Parameters
- $T_{max} = 0.03$ Nm
- $D = 0.001$ Nms/rad
- $\omega_{lim} = 15$ rad/s

Variables
- Torque $\Rightarrow$ through
- $\omega \Rightarrow$ across

* r is derived from ω_{lim}, D and T_{max}

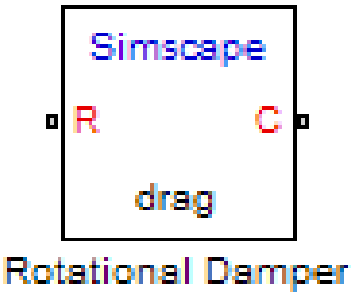
Node Declarations

Domain	Node declaration
Electrical	foundation.electrical.electrical
Hydraulic	foundation.hydraulic.hydraulic
Magnetic	foundation.magnetic.magnetic
Mechanical Rotational	foundation.mechanical.rotational.rotational
Mechanical Translational	foundation.mechanical.translational.translational
Pneumatic	foundation.pneumatic.pneumatic
Thermal	foundation.thermal.thermal

Parameters

```
D = { 0.001, '(N*m)*s/rad'};
```

Specifying Port Labels




```
nodes
    R = foundation.mechanical.rotational.rotational; % R:left
    C = foundation.mechanical.rotational.rotational; % C:right
end
```

Setup Section

Setup

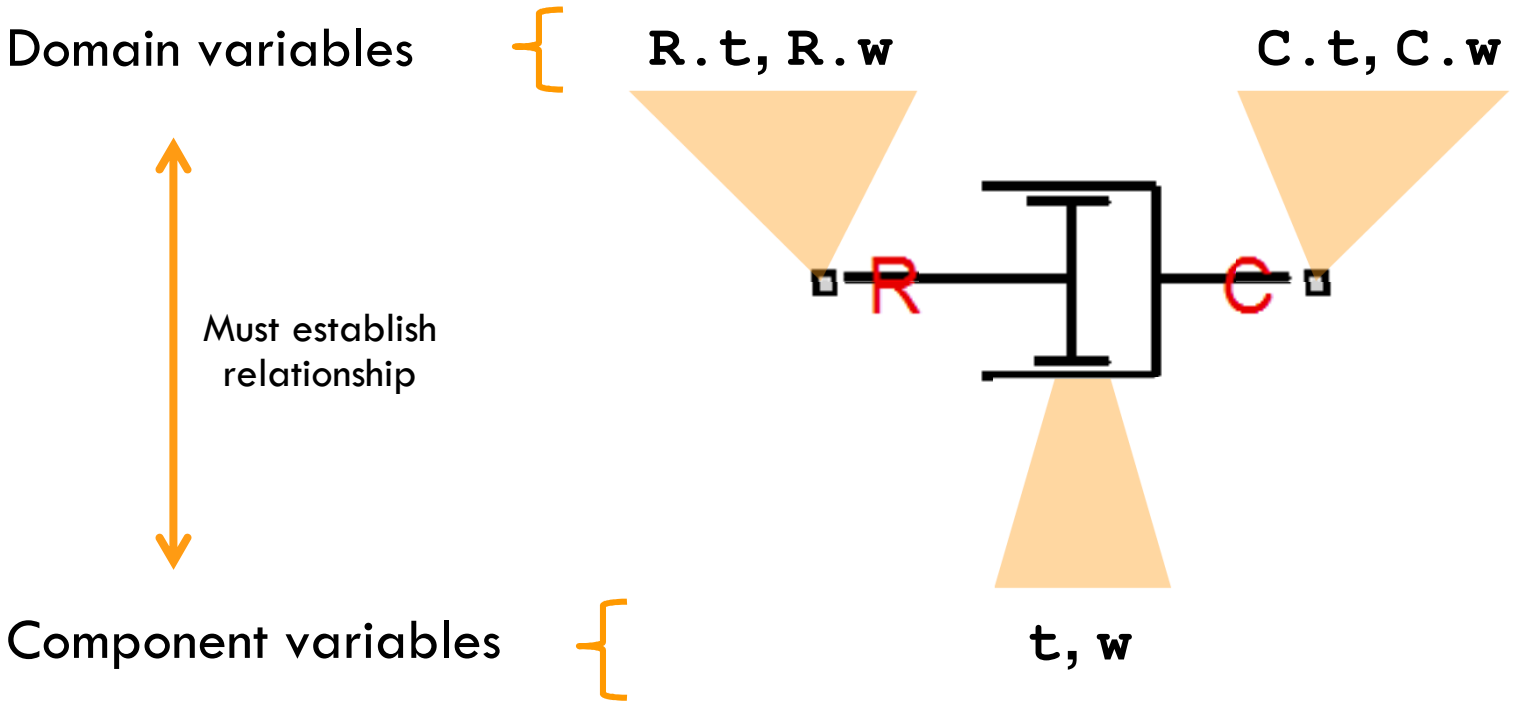
- Perform intermediate calculations
- Ensure parameter validity
- Specify through and across variable relationships between components nodes
- Initialize system variables

$$Torque = \begin{cases} D \cdot \omega & |\omega| \le \omega_{\text{lim}} \\ T_{\max} \cdot \dfrac{\omega}{|\omega| + r} & |\omega| > \omega_{\text{lim}} \end{cases}$$

- Specify through and across variables between two nodes
- Ensure parameters are greater than 0.

Through and Across Variables

```
through(t, R.t, C.t)
```



Across and Through Variables

Physical Domain	Across Variable	Through Variable
Electrical	Voltage	Current
Hydraulic	Pressure	Flow Rate
Magnetic	Magnetomotive Force	Flux
Mechanical Rotational	Angular Velocity	Torque
Mechanical Translational	Translational Velocity	Force
Pneumatic	Pressure and Temperature	Mass Flow Rate and Heat Flow
Thermal	Temperature	Heat Flow

Equations Section

Equations

Establish the mathematical relationship between variables, parameters, inputs and outputs

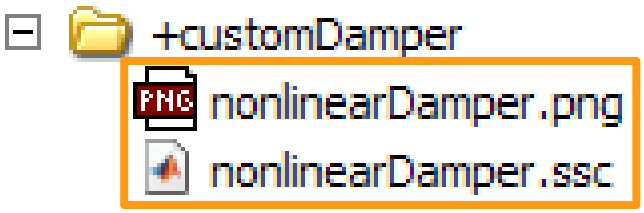
== is a symmetric operator, not an assignment operator

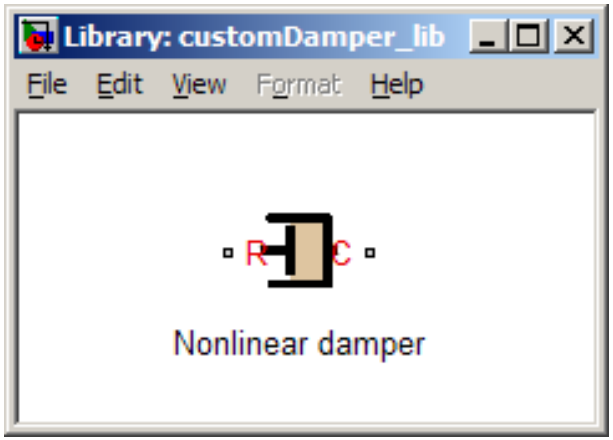
$$Torque = \begin{cases} D \cdot \omega & |\omega| \le \omega_{lim} \\ T_{max} \cdot \dfrac{\omega}{|\omega| + r} & |\omega| > \omega_{lim} \end{cases}$$

```
equations
    if abs(w) <= w_linRange
        t == D*w;
    else
        t == t_max*w/(abs(w)+(t_max/D - w_linRange));
    end
end
```

$$r = \frac{T_{max}}{D} - \omega_{lim}$$

Customize Block Icons





Supported image file formats: JPG, BMP, PNG

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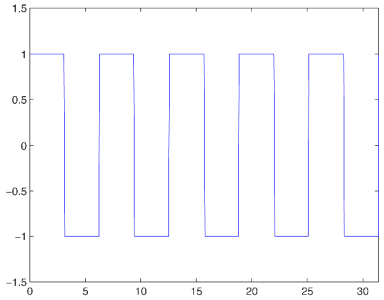
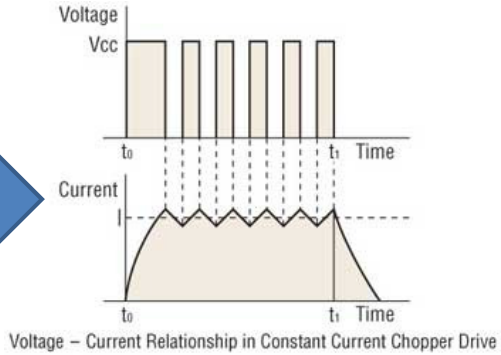
Estimating Parameter workflow

- Test data → Measurement → Log Data



Test Signal
(Ex. DC voltage)

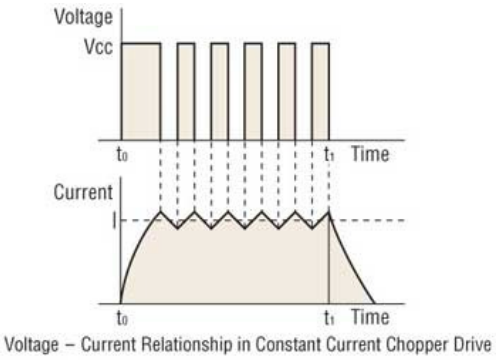
Measurement by sensor
(Ex. Motor current)



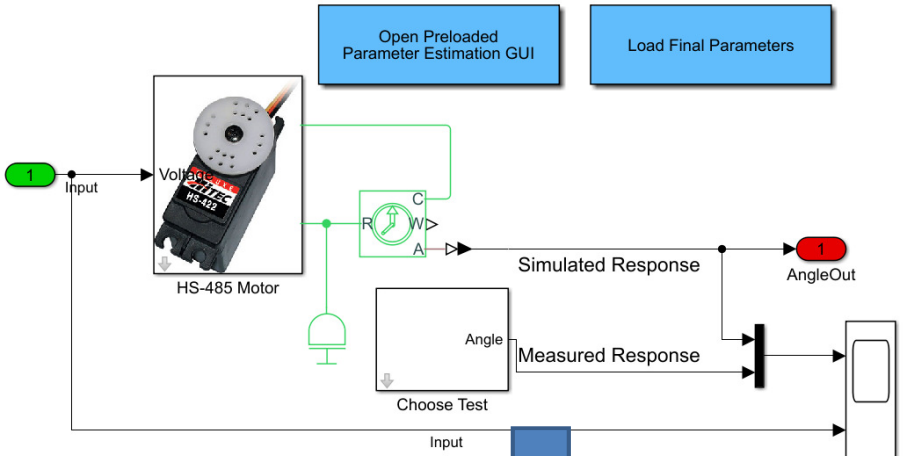
Voltage – Current Relationship in Constant Current Chopper Drive

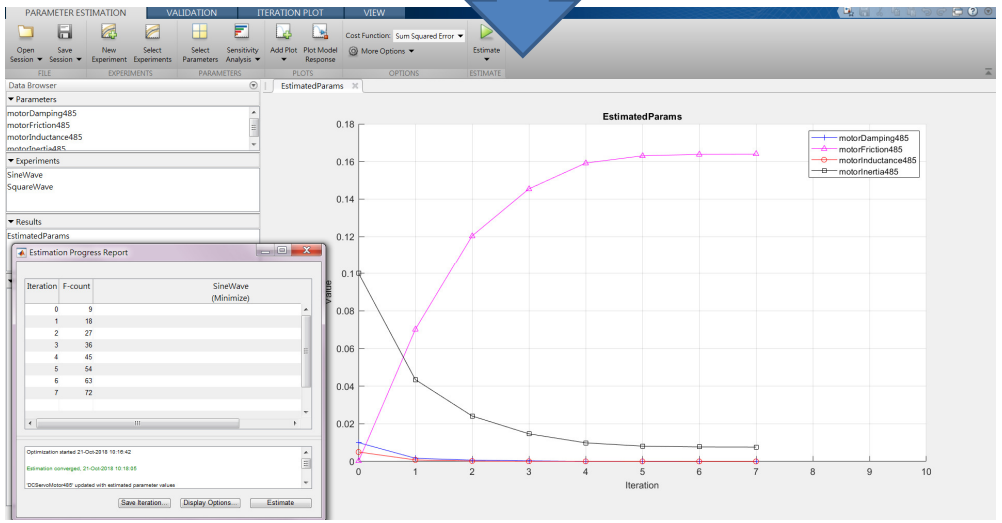
Log I/O Data
by file

Estimating Parameter workflow



Voltage – Current Relationship in Constant Current Chopper Drive





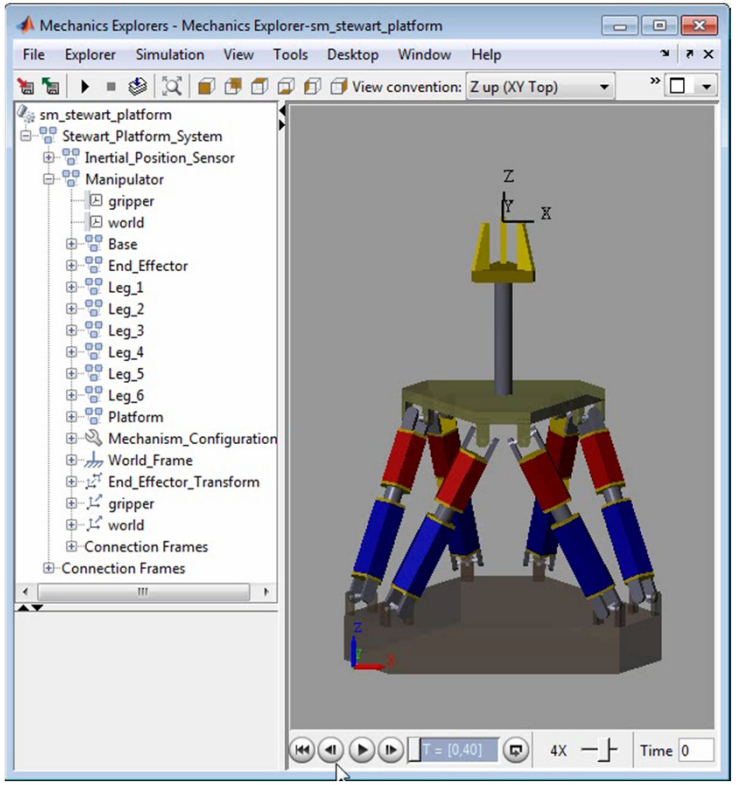
Import data to Simulink model and estimate parameter by GUI

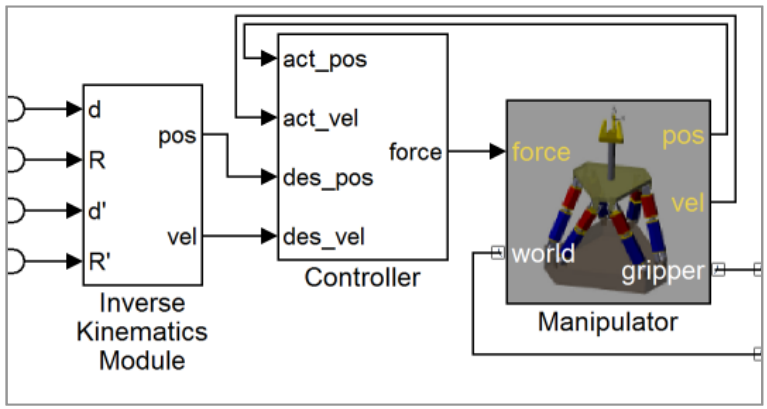
Agenda

- What's new in Simscape Family
- Building Dynamic model with Simscape
  - Foundation library
  - Simscape language
  - Estimate Model Parameter Values
- Simscape Multibody
  - Multibody introduction
  - Import from CAD

Multibody Applications Stewart Platform

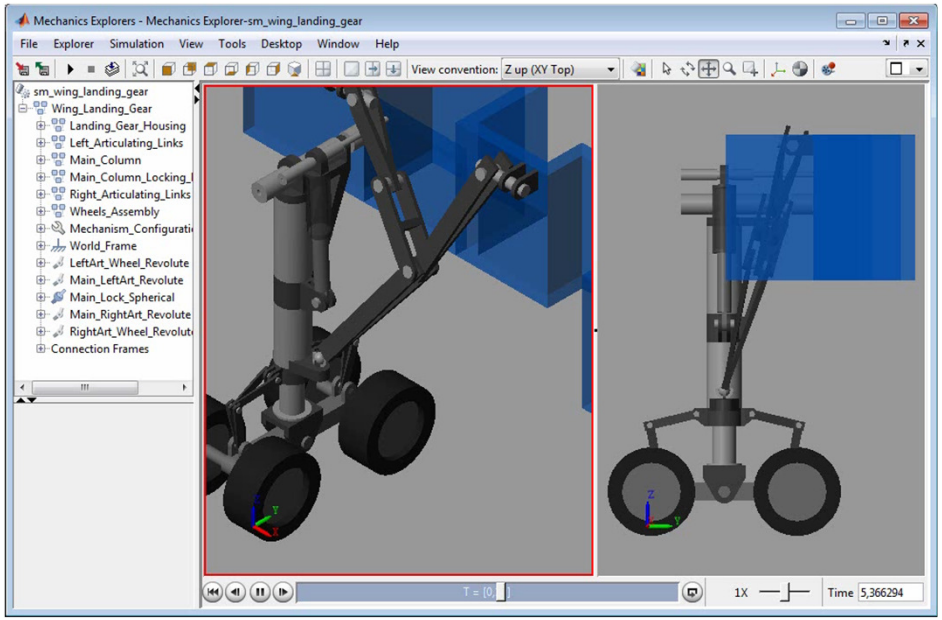
- Platform positions gripper to track reference trajectory
  - Inverse kinematics module and controller defined in Simulink
- Multibody helps you:
  - Design controller
    - Control-loop structure, gains
  - Optimize system
    - Component sizes and actuator dynamics

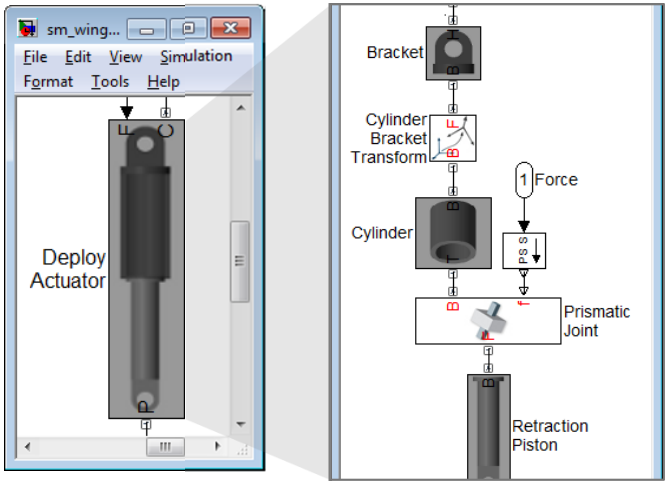




Multibody Applications
Landing Gear

- Deploys and retracts based on input signal
  - Includes control system, actuator dynamics
- Multibody helps you:
  - Determine and refine actuator requirements
  - Test loading scenarios
  - Test parameter variations

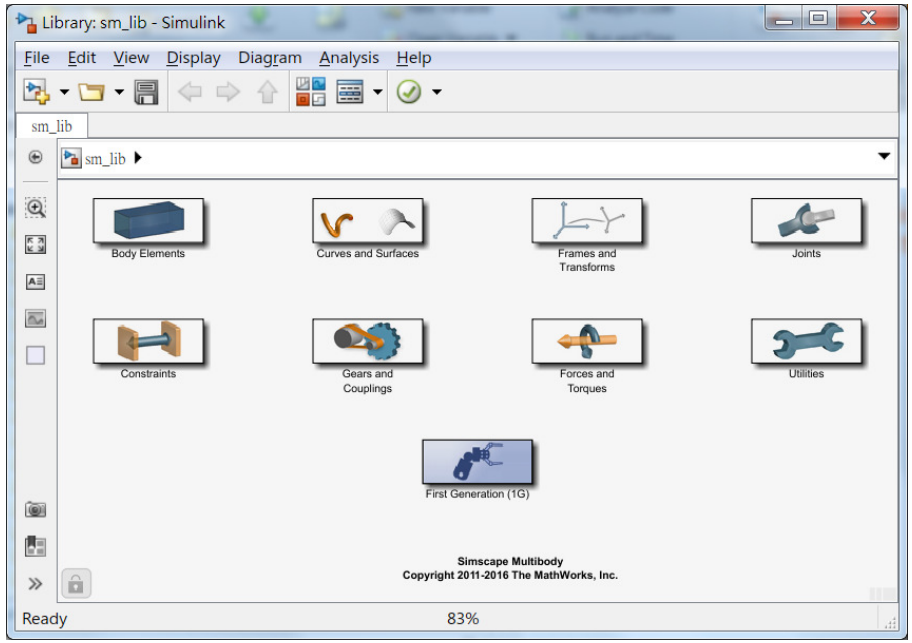


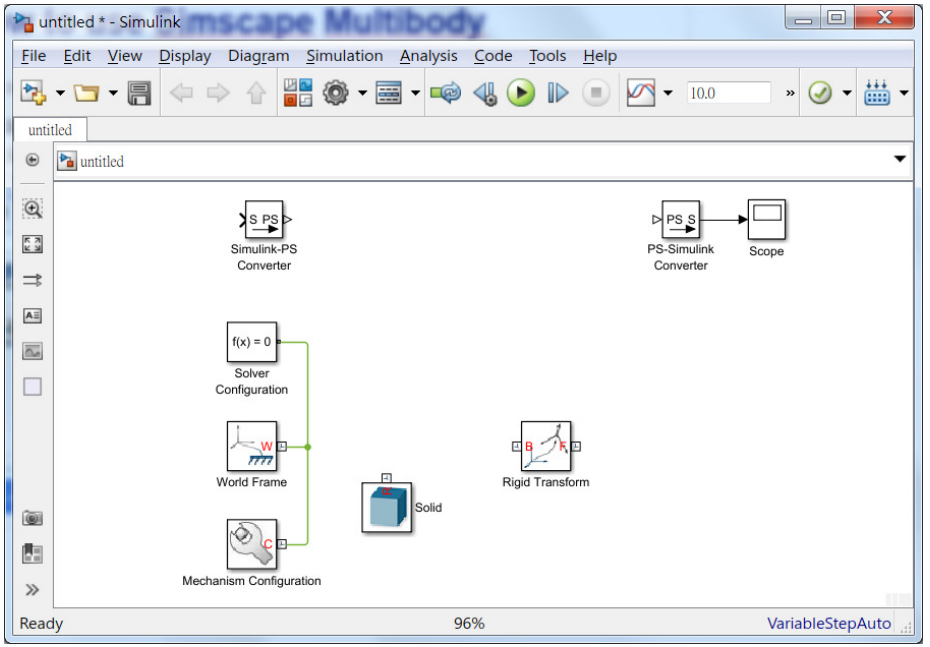


How to use Simscape Multibody

- >>smnew

Library will open and model will be created with needed blocks.





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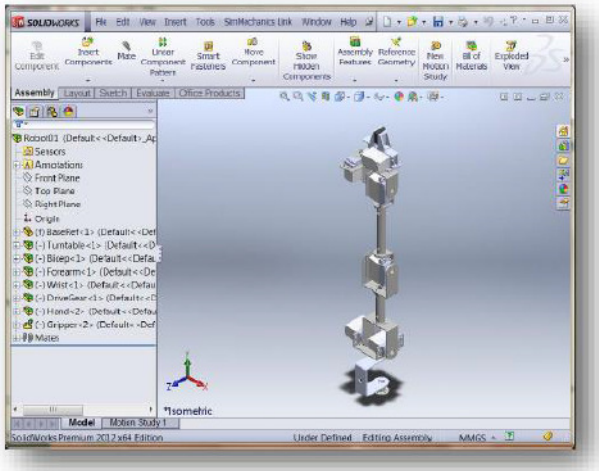
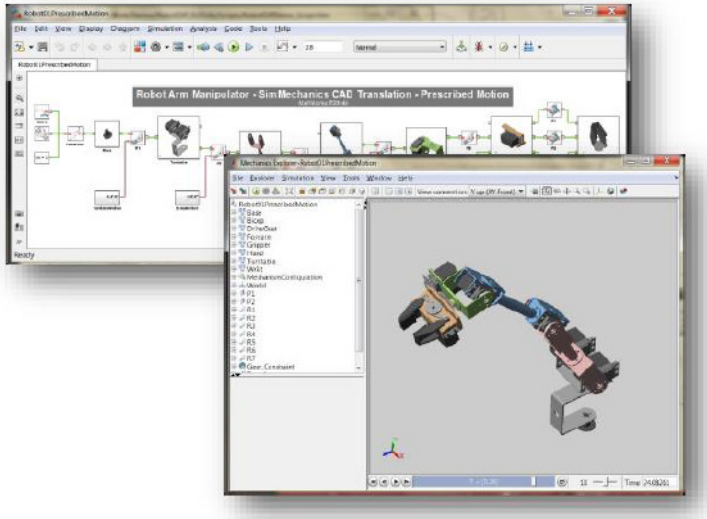
Robot design from CAD tool to Simscape Multibody

SolidWorks Model



Simscape Multibody Model



Import models from Autodesk Inventor®, PTC® Creo™ , and SolidWorks

Download smlink from Mathworks

Simscape Multibody Link

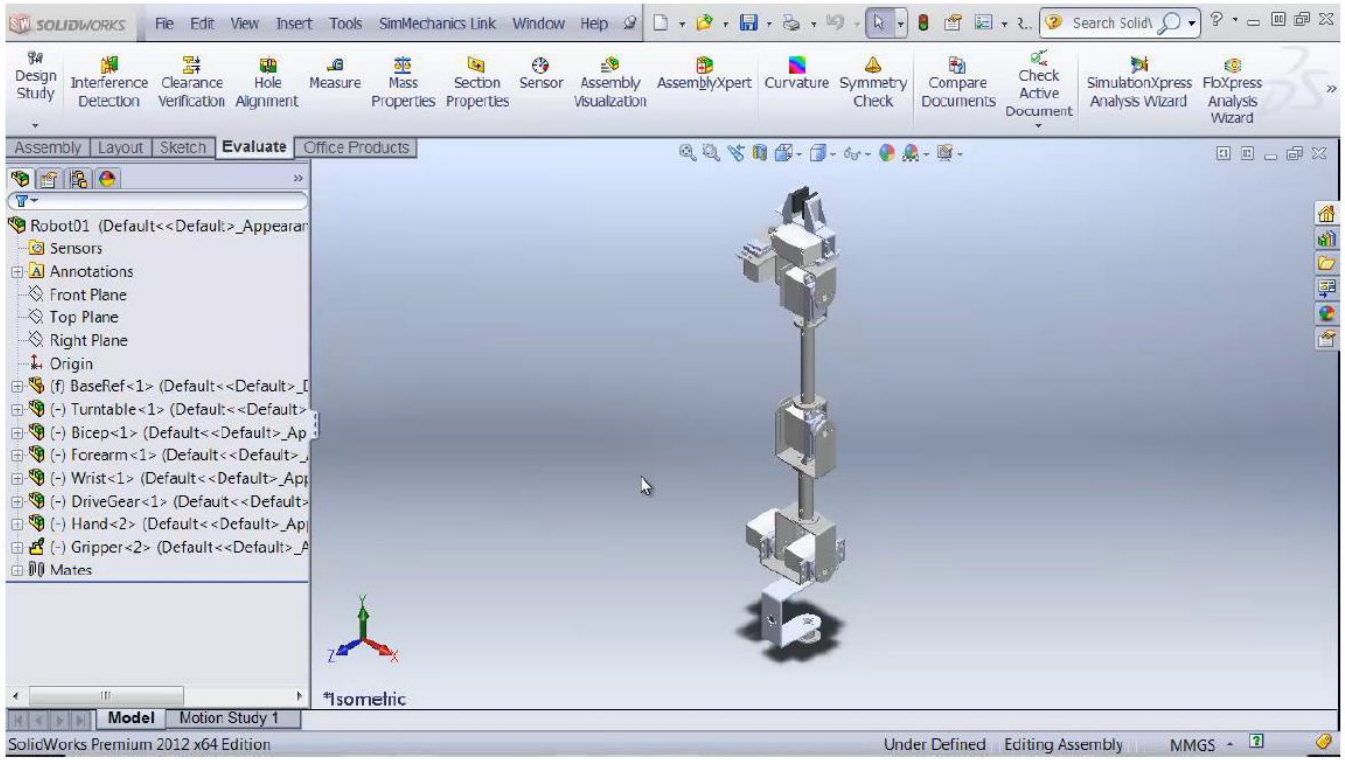
Simscape Multibody Link works with Simscape Multibody 3.0 and higher (MATLAB R2008b and higher). Supported operating systems for your CAD platform are win32 and win64 except where noted below.

CAD Tool	Releases Supported	MATLAB Release
SolidWorks	2001Plus and higher	R2008b and higher
Wildfire, Creo (formerly Pro/ENGINEER)	WildFire 2.0 and higher[1], Creo 1.0 and higher	R2008b and higher
Autodesk Inventor	2009 and higher	R2009a and higher

[1]PTC Wildfire 4.0 on win64 is not supported for MATLAB Release R2012b and higher

- https://www.mathworks.com/products/simmechanics/download_smlink.html

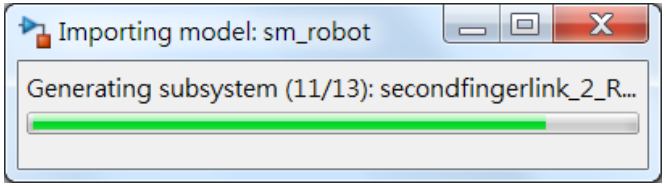
Install smlink to CAD tool and export xml file from CAD tool

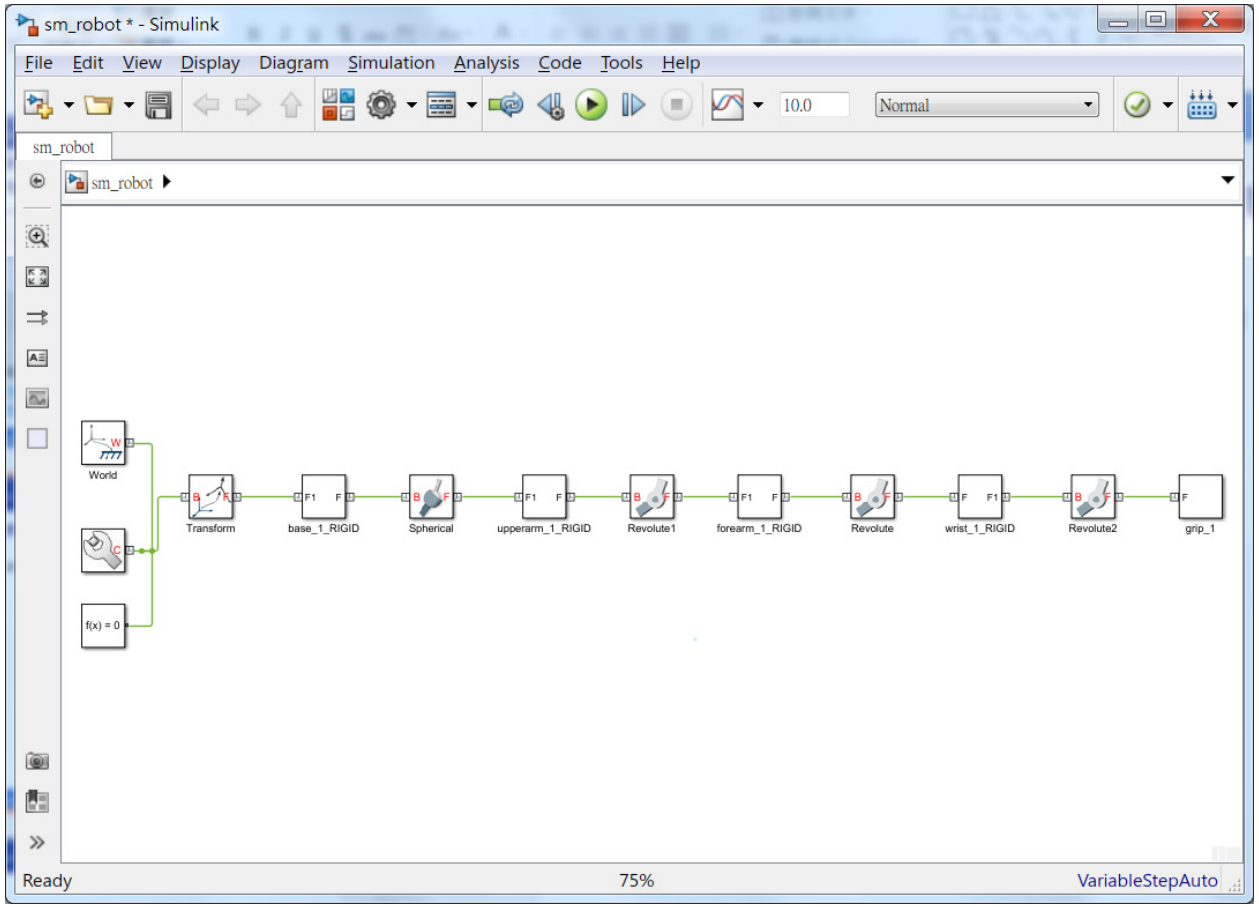


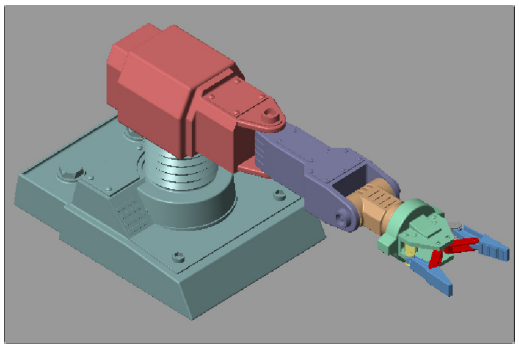
- https://www.mathworks.com/help/physmod/smlink/ug/installing-and-linking-simmechanics-link-software.html

Import xml file to Simulink

- >>smimport('sm_robot.xml')

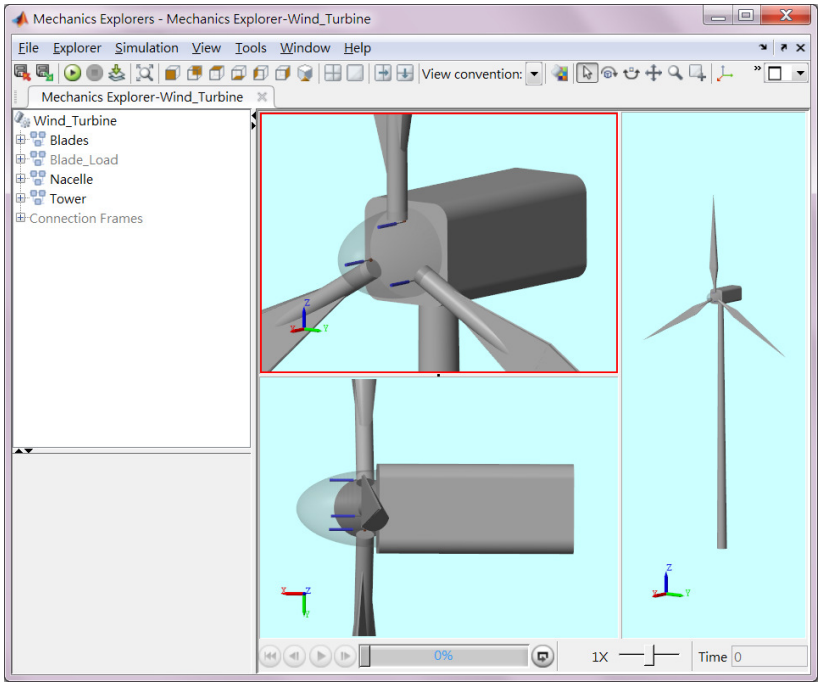


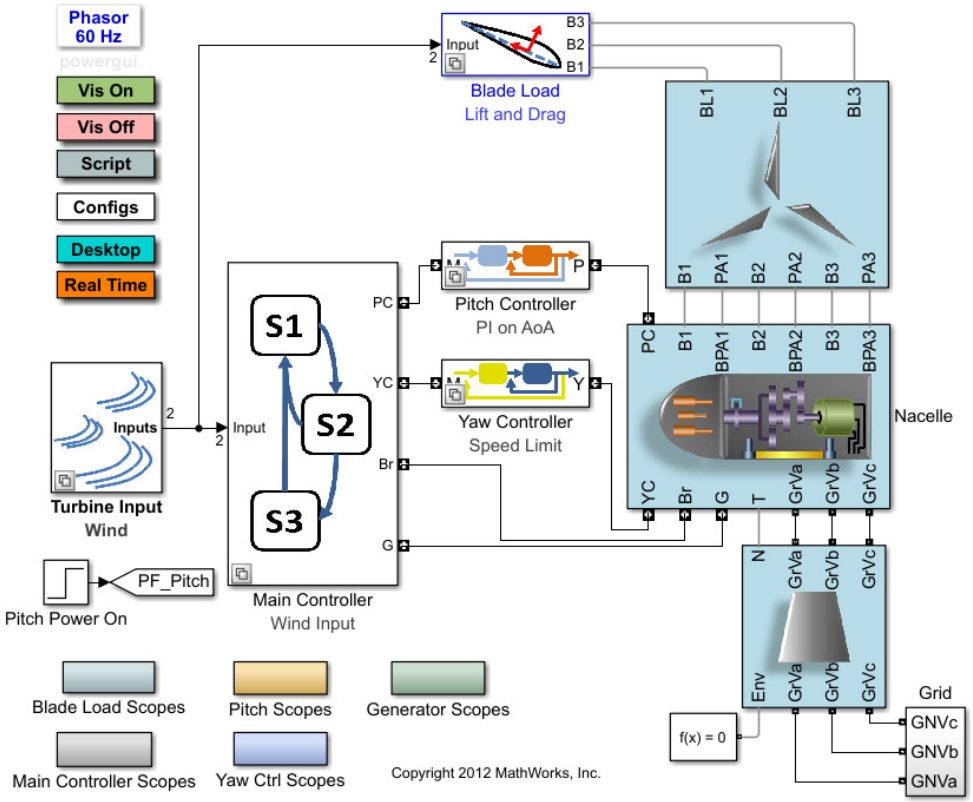




Multi-domain demo (Wind Turbine)

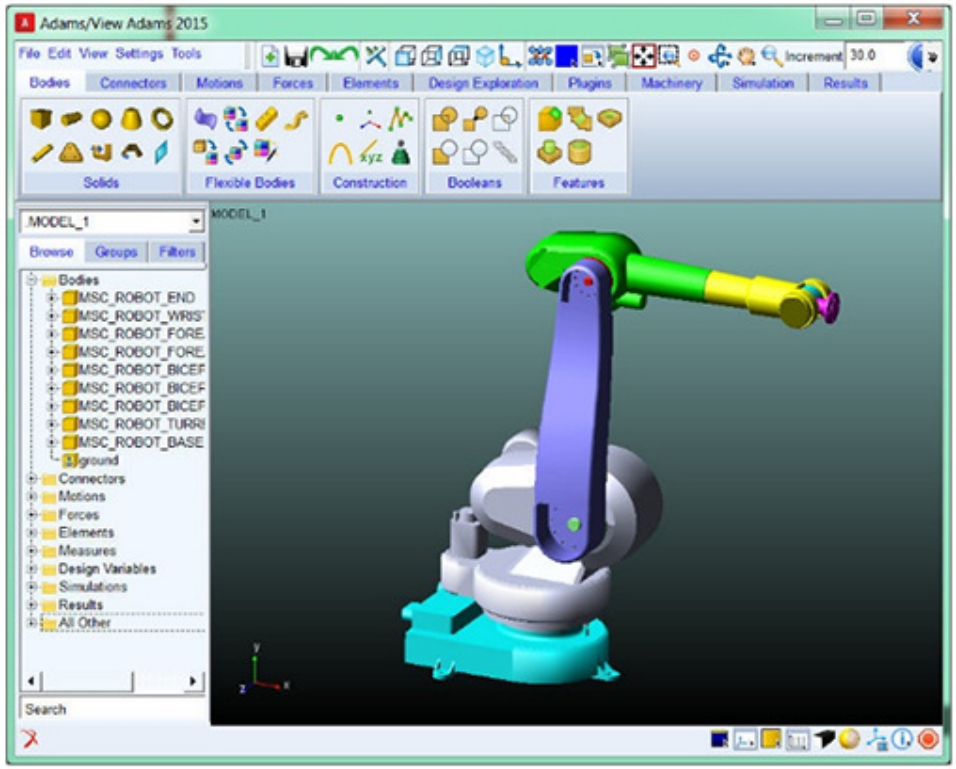
- Simscape Electrical
- Simscape Driveline
- Simscape Multibody

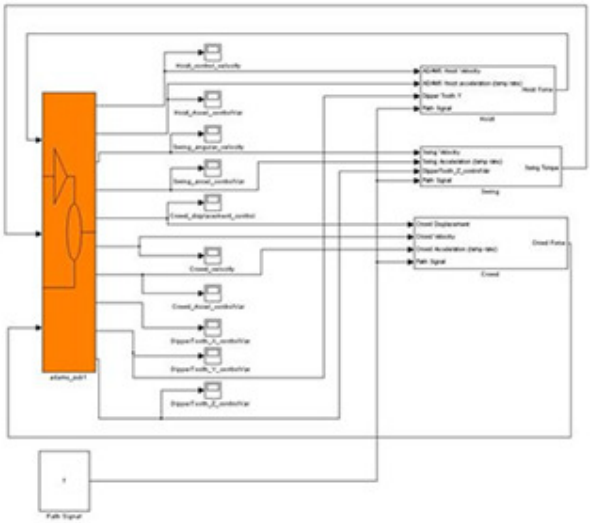




Co-Sim with 3rd party software

- Co-Sim block : Provide by 3rd party tool
- Run 3rd party tool by Simulink simulation kernel





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