TECHSOURCE ASCENDAS SYSTEMS MathWorks Authorized Reseller MATLAB & SIMULINK

Physical Modelling Workshop

August 12, 2022

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R2022a

Our software is used to design the products we rely on every day

Automobiles

Commercial Aircraft

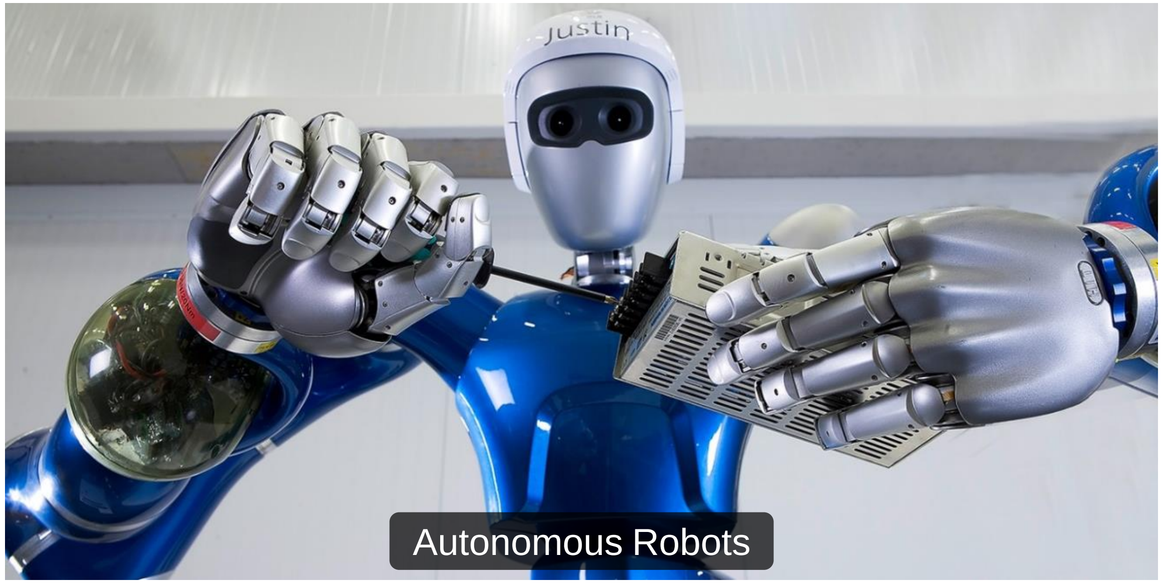
Smartphones

Consumer Goods

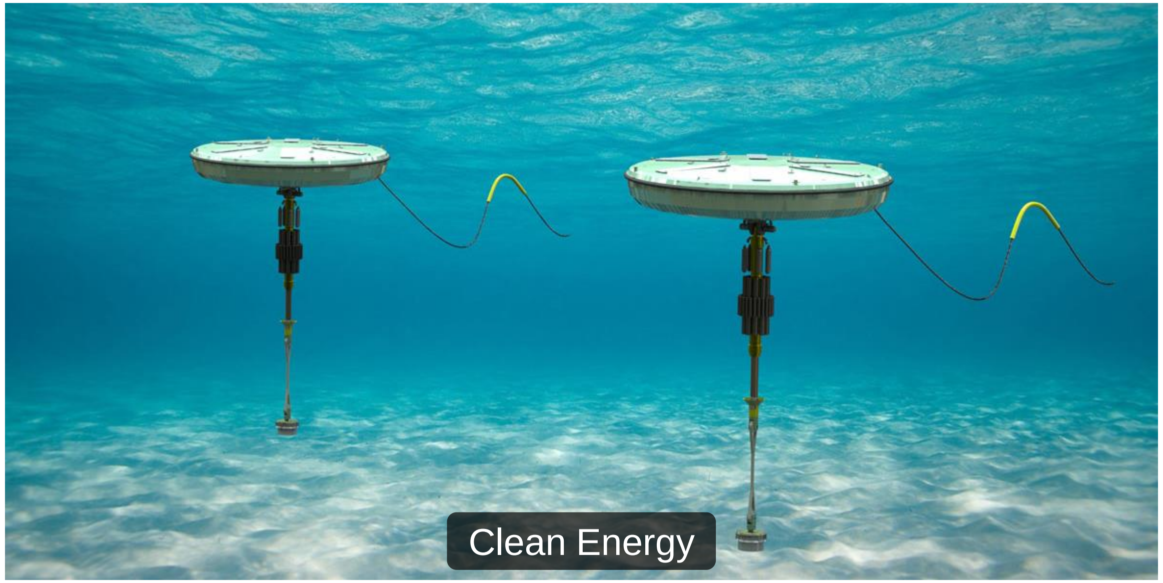
And the breakthroughs transforming how we live, learn, and work

Solar-Powered Cars

Advanced Prosthetics



Autonomous Robots



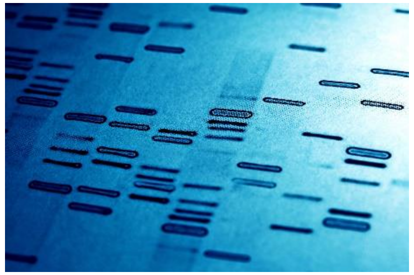
Clean Energy

Our Customers / Key Industries

Aerospace and Defense

Automotive

Biological Sciences


Biotech and Pharmaceutical

Communications

Electronics

Energy Production

Financial Services

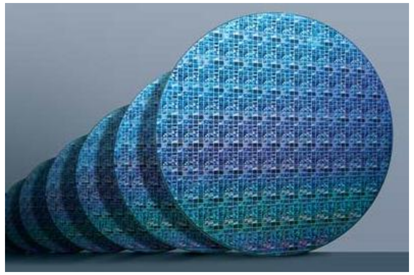
Industrial Machinery

Medical Devices

Process Industries

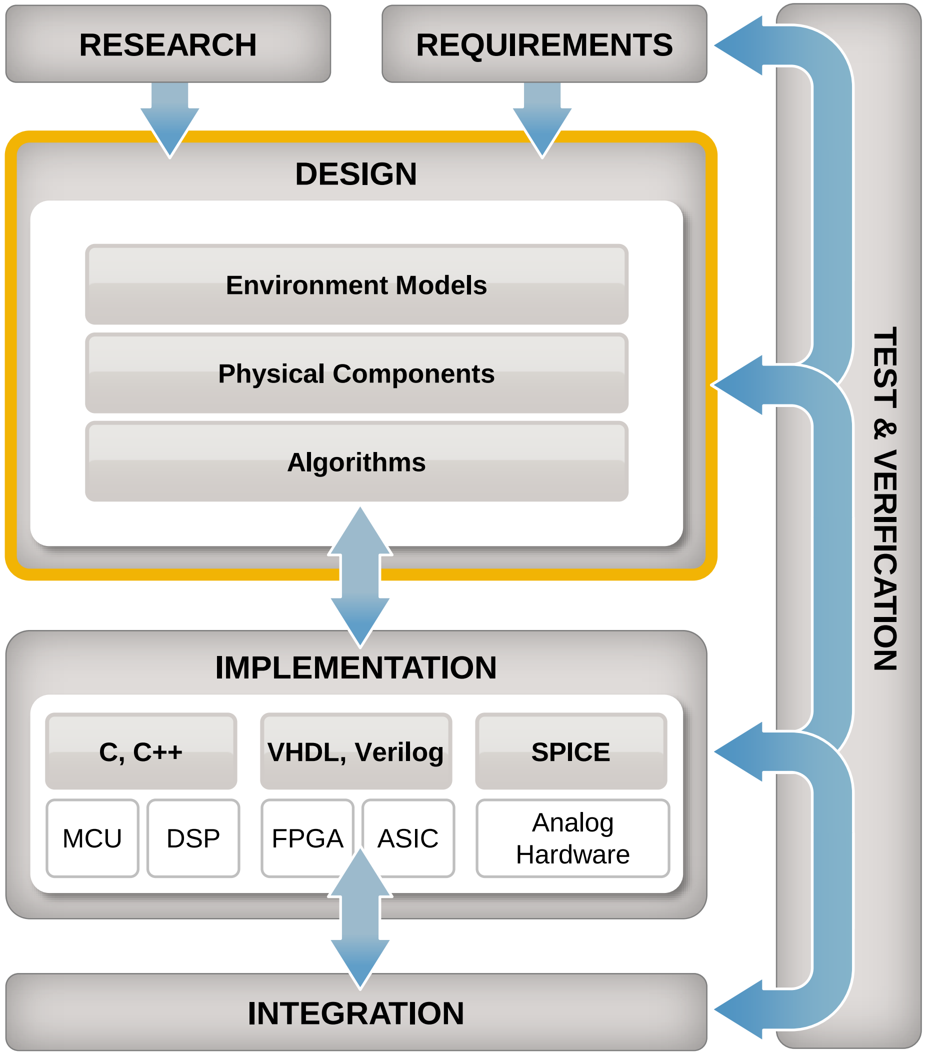
Neuroscience

Railway Systems


Semiconductors

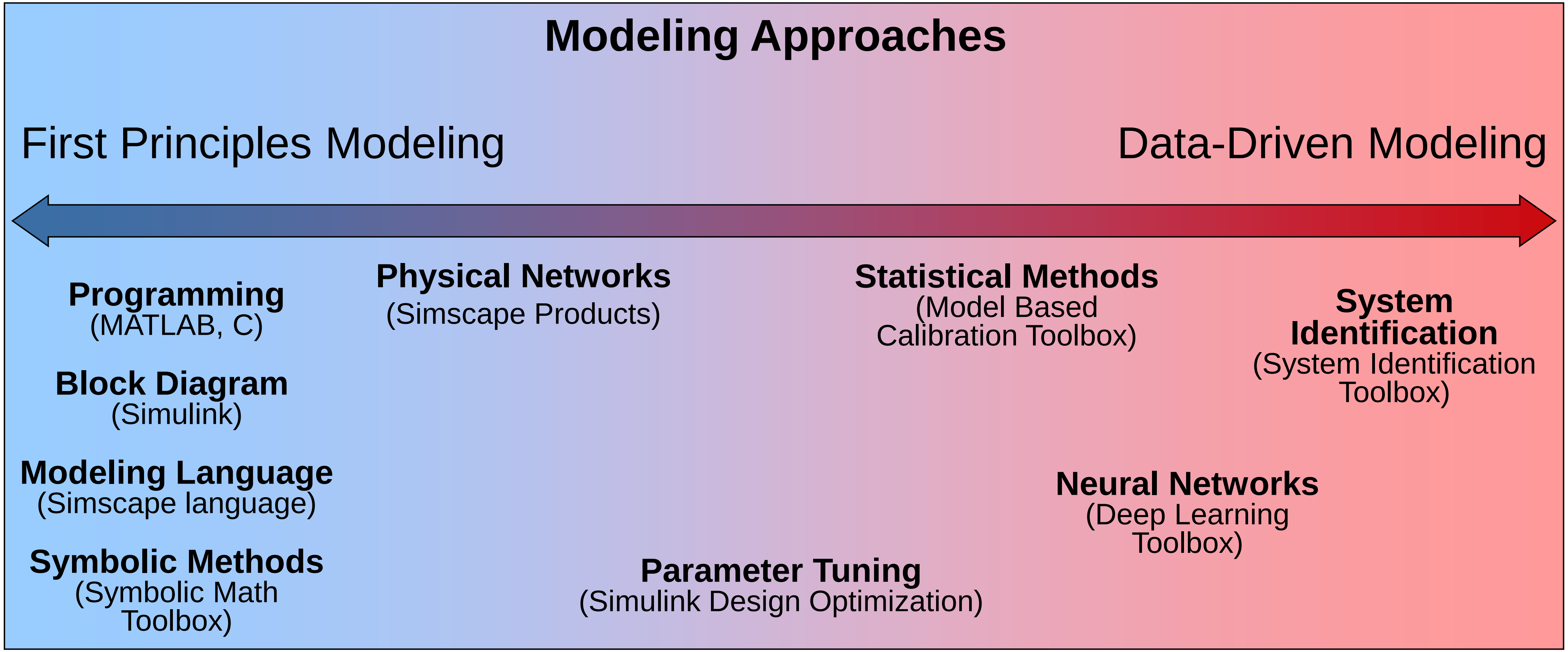
Software and Internet

MathWorks developed Model-Based Design with the auto industry



First MAB Germany 1998

Modeling Physical Systems With MathWorks Products



Modeling Approaches

First Principles Modeling

Data-Driven Modeling

Programming
(MATLAB, C)

Block Diagram
(Simulink)

Modeling Language
(Simscape language)

Symbolic Methods
(Symbolic Math Toolbox)

Physical Networks
(Simscape Products)

Parameter Tuning
(Simulink Design Optimization)

Statistical Methods
(Model Based Calibration Toolbox)

Neural Networks
(Deep Learning Toolbox)

System Identification
(System Identification Toolbox)

Simulink

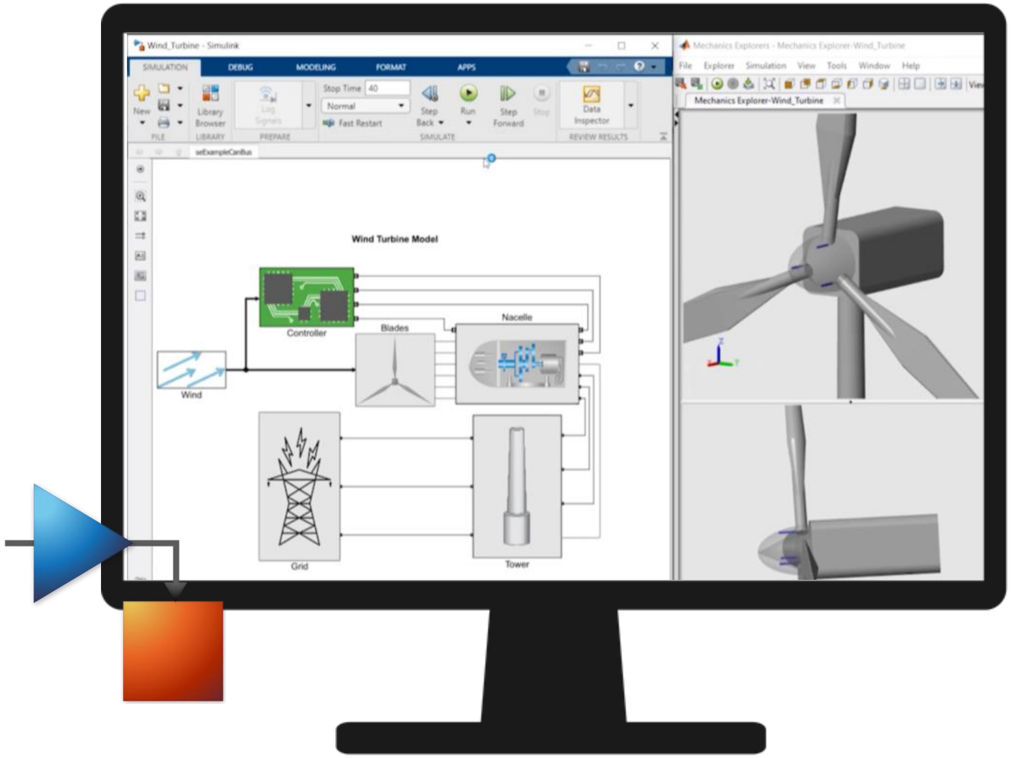
check earlier and often

easy integration

used worldwide

result-oriented

```
>> url="www.mathworks.com/products/simulink.html"
>> web(url);
```



- Graphic Environment
- Integration with MATLAB
- Multi-domain modelling
- Model-Based Design

Transforming the way Engineers work.

Simscape

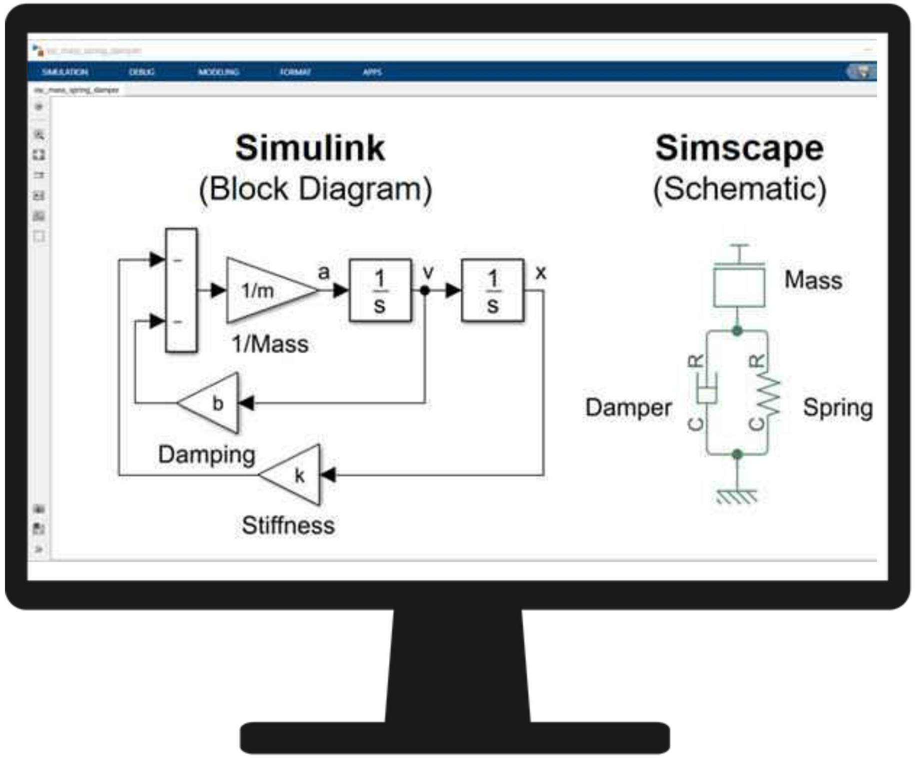
teaching-oriented

scalable

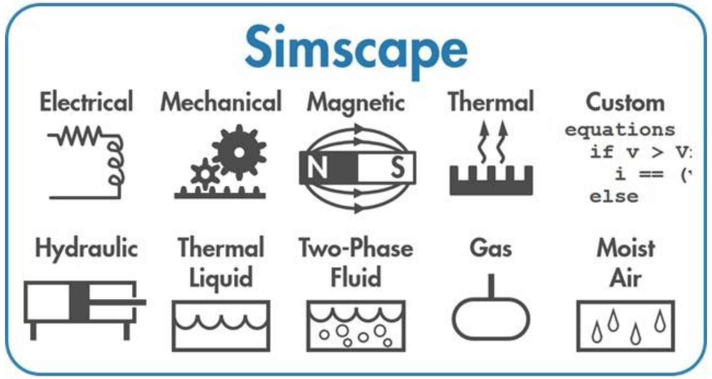
software integration

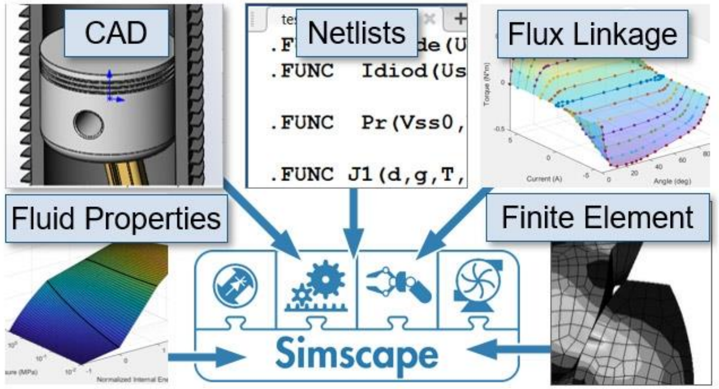
multi-physics

Intuitive creation of multidomain models



$$F_{\text{ext}} = m\ddot{x} + b\dot{x} + kx$$





For more info on **Simscape**
check the documentation

Modeling Physical Systems With MathWorks Products

Modeling Approaches

First Principles Modeling ⟷ Data-Driven Modeling

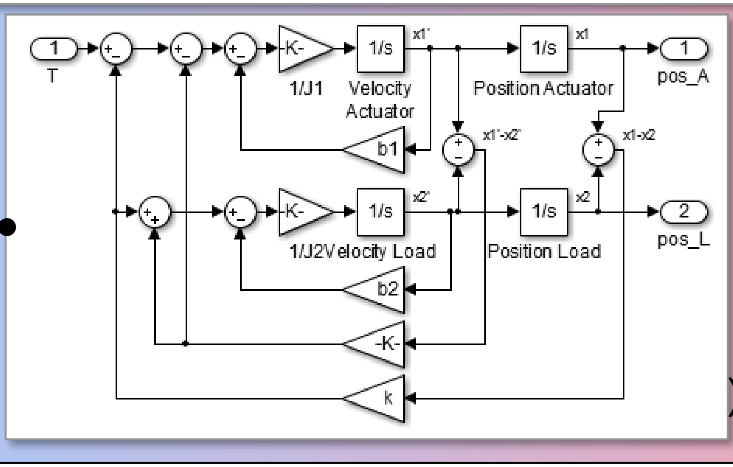
Programming
(MATLAB, C)

Block Diagram
(Simulink)

Modeling Language
(Simscape language)

Symbolic Methods
(Symbolic Math Toolbox)

$$J_1 x_1'' = -b_1 x_1' - k(x_1 - x_2) - b_{12}(x_1' - x_2') + T$$
$$J_2 x_2'' = -b_2 x_2' + k(x_1 - x_2) - b_{12}(x_1' - x_2')$$



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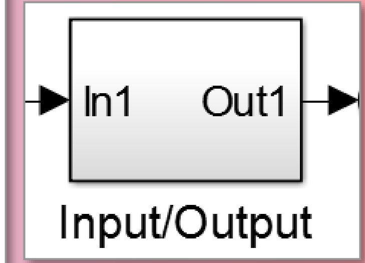

Input/Output

Modeling Physical Systems With MathWorks Products

Modeling Approaches

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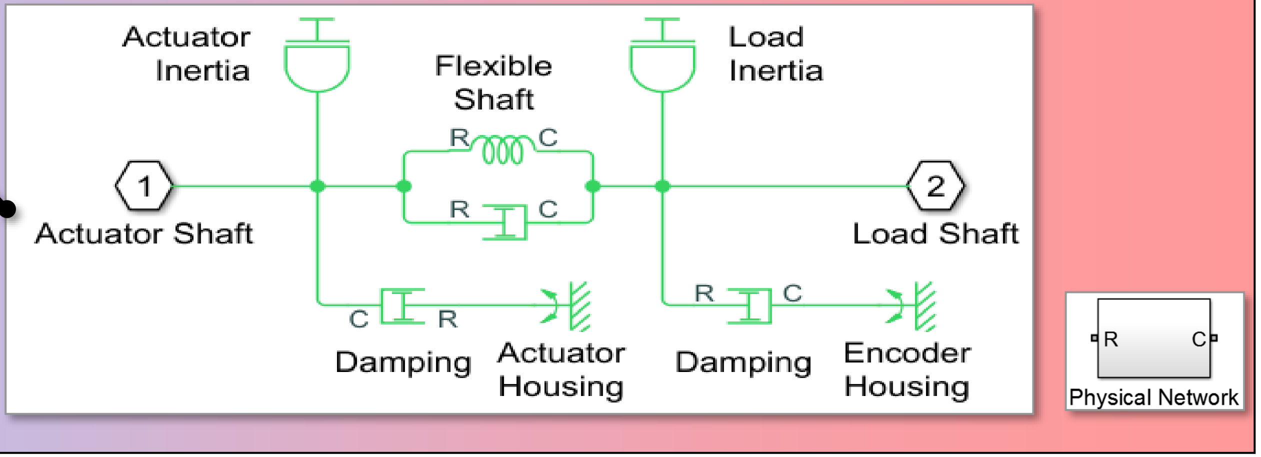
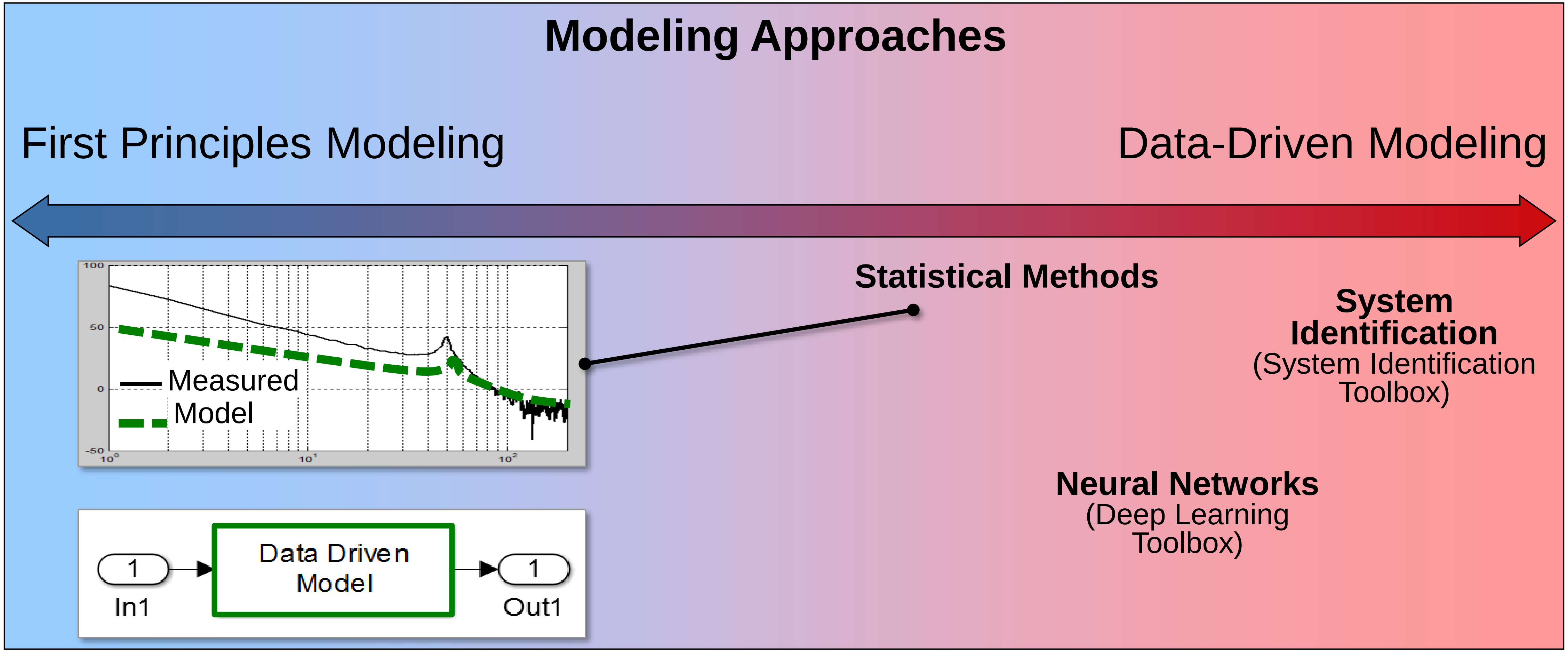
Physical Networks
(Simscape Products)



Modeling Physical Systems With MathWorks Products



Modeling Approaches

First Principles Modeling

Data-Driven Modeling

Statistical Methods

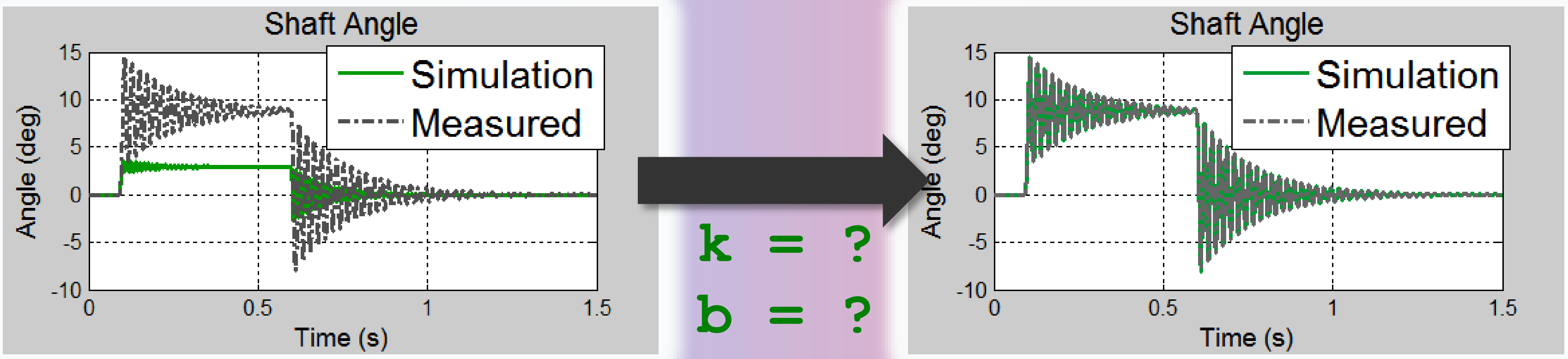
System Identification
(System Identification Toolbox)

Neural Networks
(Deep Learning Toolbox)

Modeling Physical Systems With MathWorks Products

Modeling Approaches

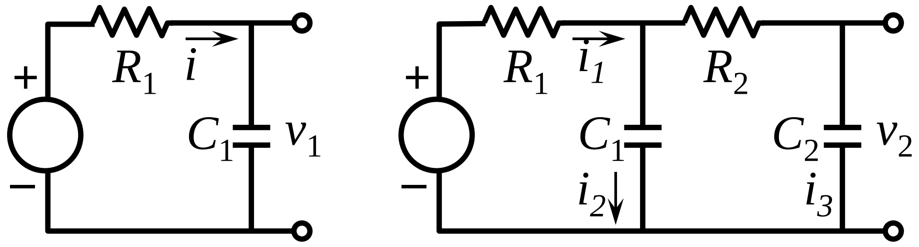
First Principles Modeling ⟷ Data-Driven Modeling



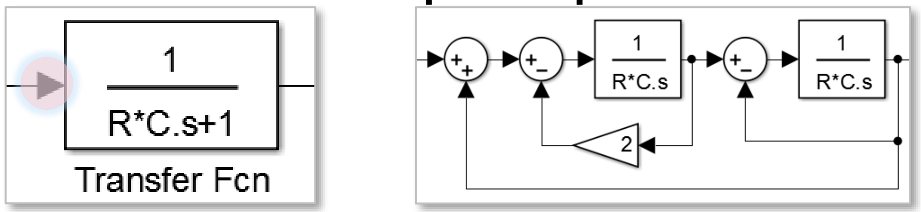
Parameter Tuning

Physical Modeling Within Simulink

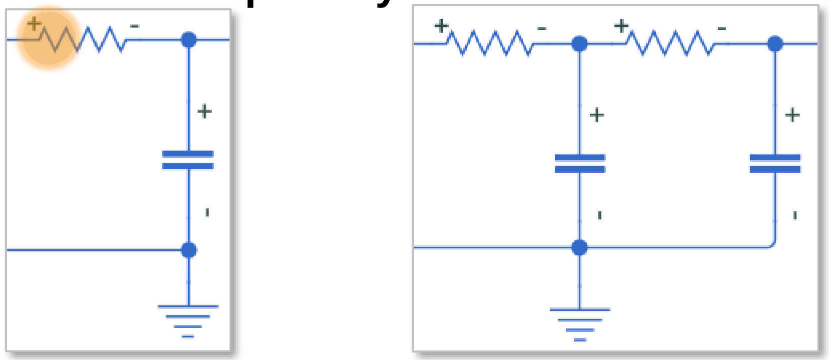
- Simulink is best known for signal-based modeling
  - Causal, or input/output
- Simscape enables bidirectional flow of energy between components
- System level equations:
  - Formulated automatically
  - Solved simultaneously
  - Cover multiple domains

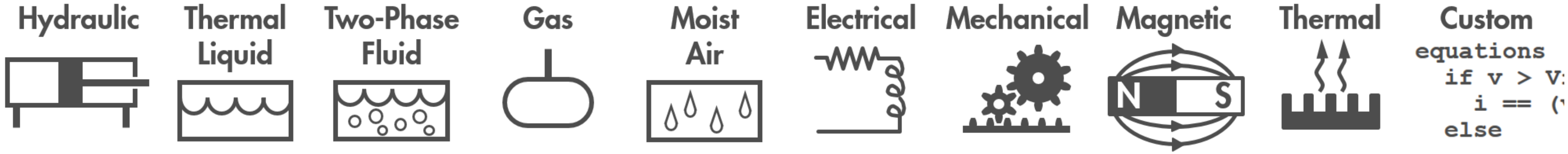


Simulink: Input/Output



Simscape: Physical Networks

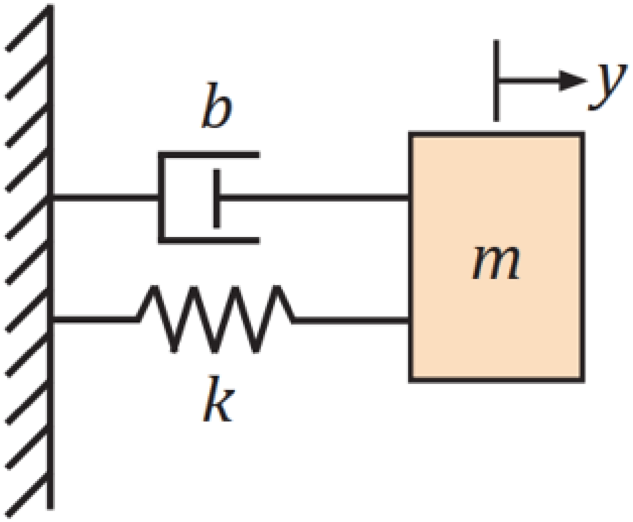




Agenda

- Introduction to Physical Modeling with Simscape
- Stateflow for Logic Driven System Modeling
- Discussion

Example : Mass-spring-damper

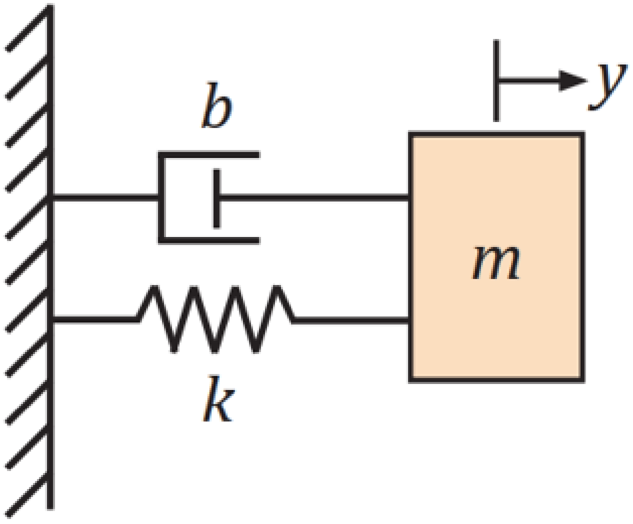


$$m\ddot{y} + b\dot{y} + ky = 0$$

Represented using diagram

Represented using equations

Example : Mass-spring-damper



Represented using diagram

$$m\ddot{y} + b\dot{y} + ky = 0$$

Represented using equations

How to convert this Mass-spring-damper to modelling

Simulink approach

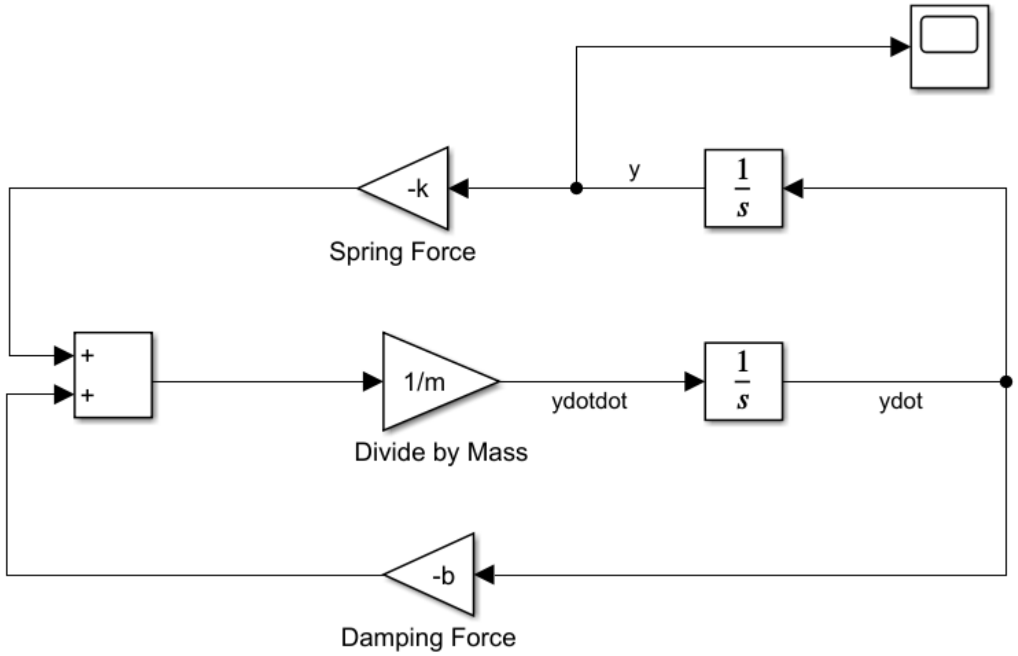
$$m\ddot{y} + b\dot{y} + ky = 0 \quad \Rightarrow \quad \ddot{y} = \frac{-b\dot{y}-ky}{m}$$

Represented using equations

This equation can be modeled in Simulink using mathematical blocks.

Simulink approach

$$\ddot{y} = \frac{-b\dot{y} - ky}{m}$$



Represented using equations

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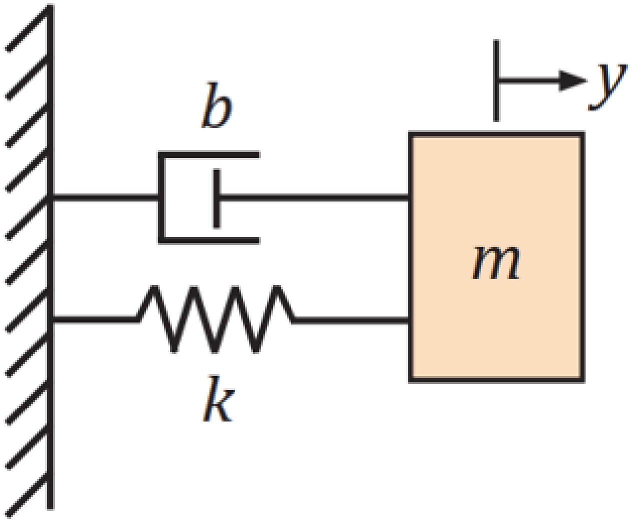
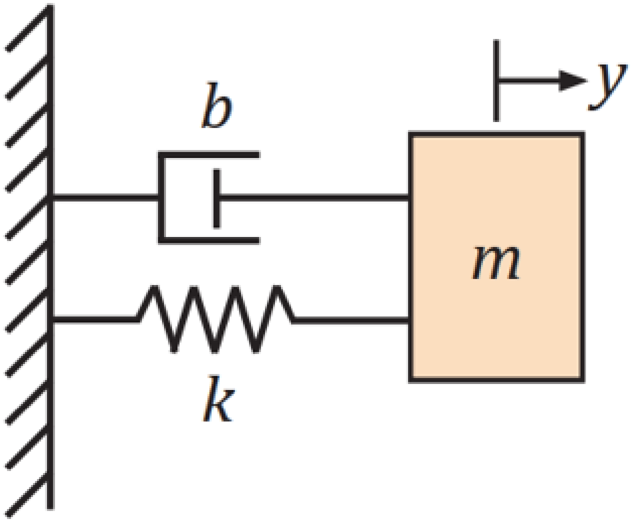
Simscape approach

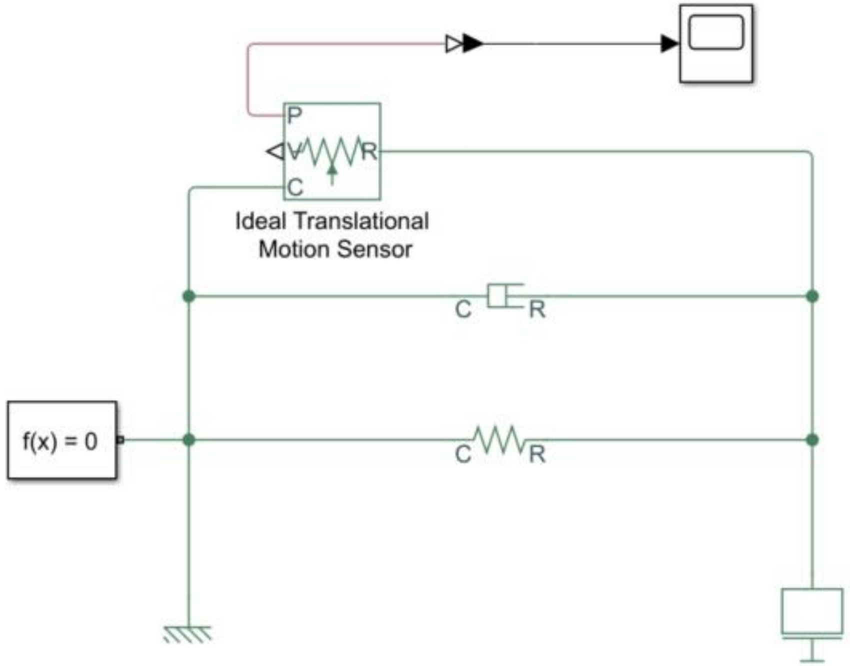


Represented using diagram

Simscape approach

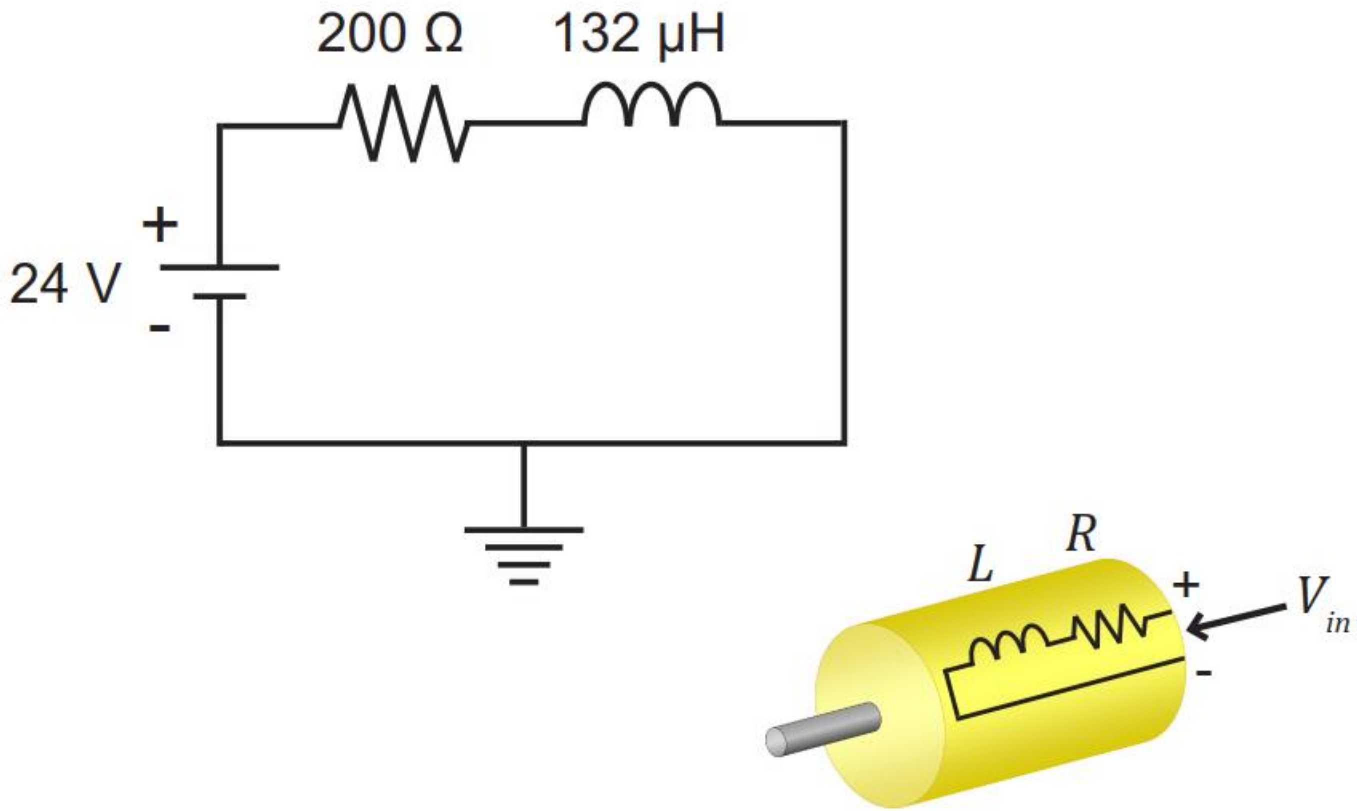


Represented using diagram



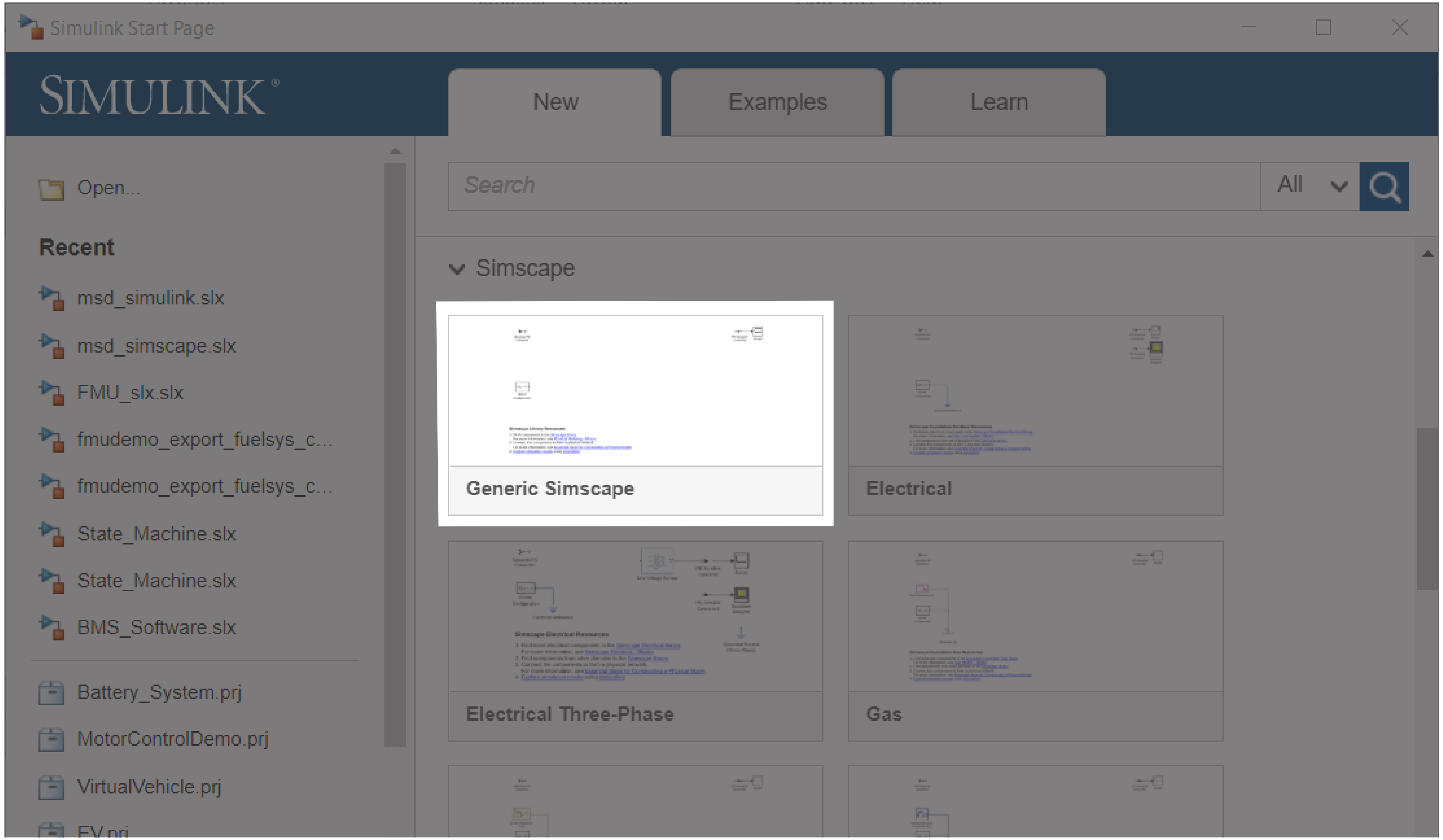
The model is built using blocks that represent physical components.

Simscape approach

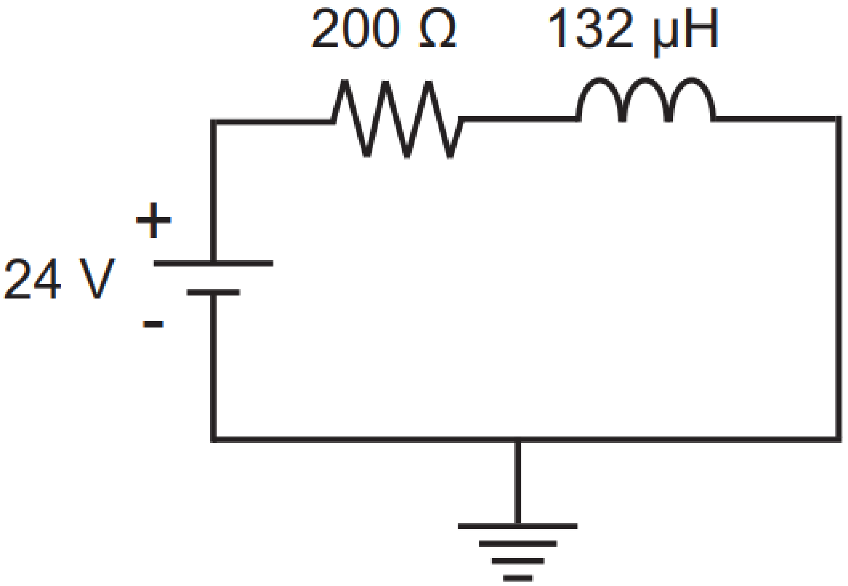


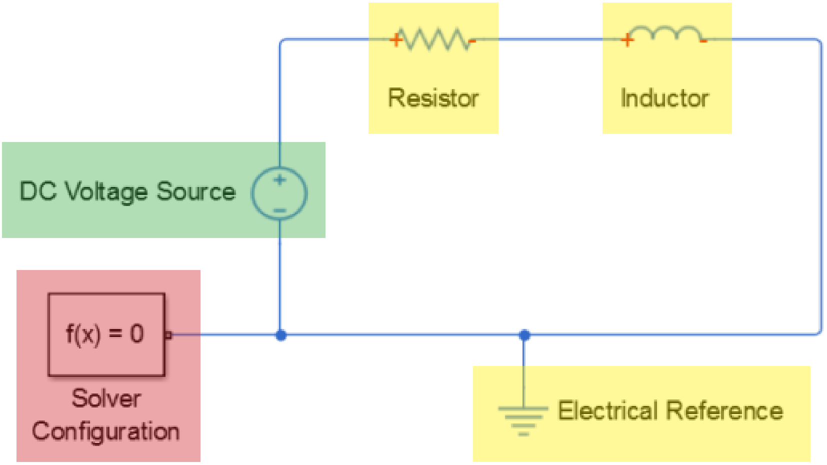
Start modelling Simscape model with RL Circuit first

Simscape approach



Simscape approach





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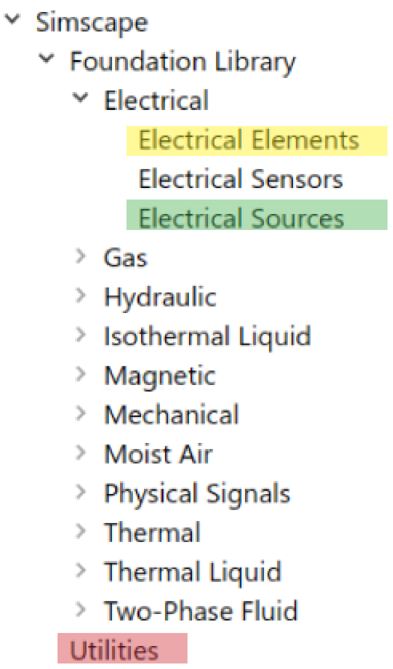
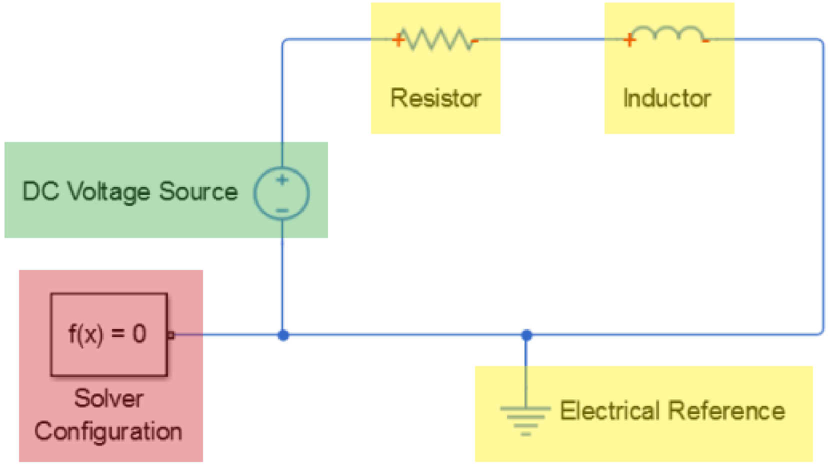


- Simscape
  - Foundation Library
    - Electrical
      - Electrical Elements
      - Electrical Sensors
      - Electrical Sources
    - Gas
    - Hydraulic
    - Isothermal Liquid
    - Magnetic
    - Mechanical
    - Moist Air
    - Physical Signals
    - Thermal
    - Thermal Liquid
    - Two-Phase Fluid
  - Utilities



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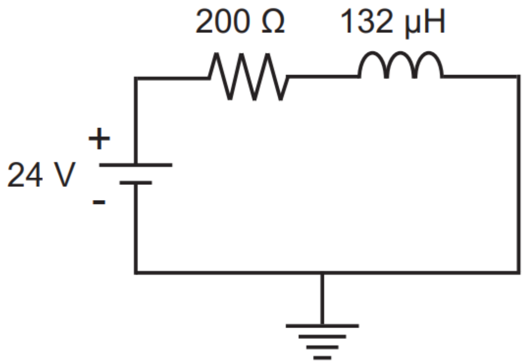
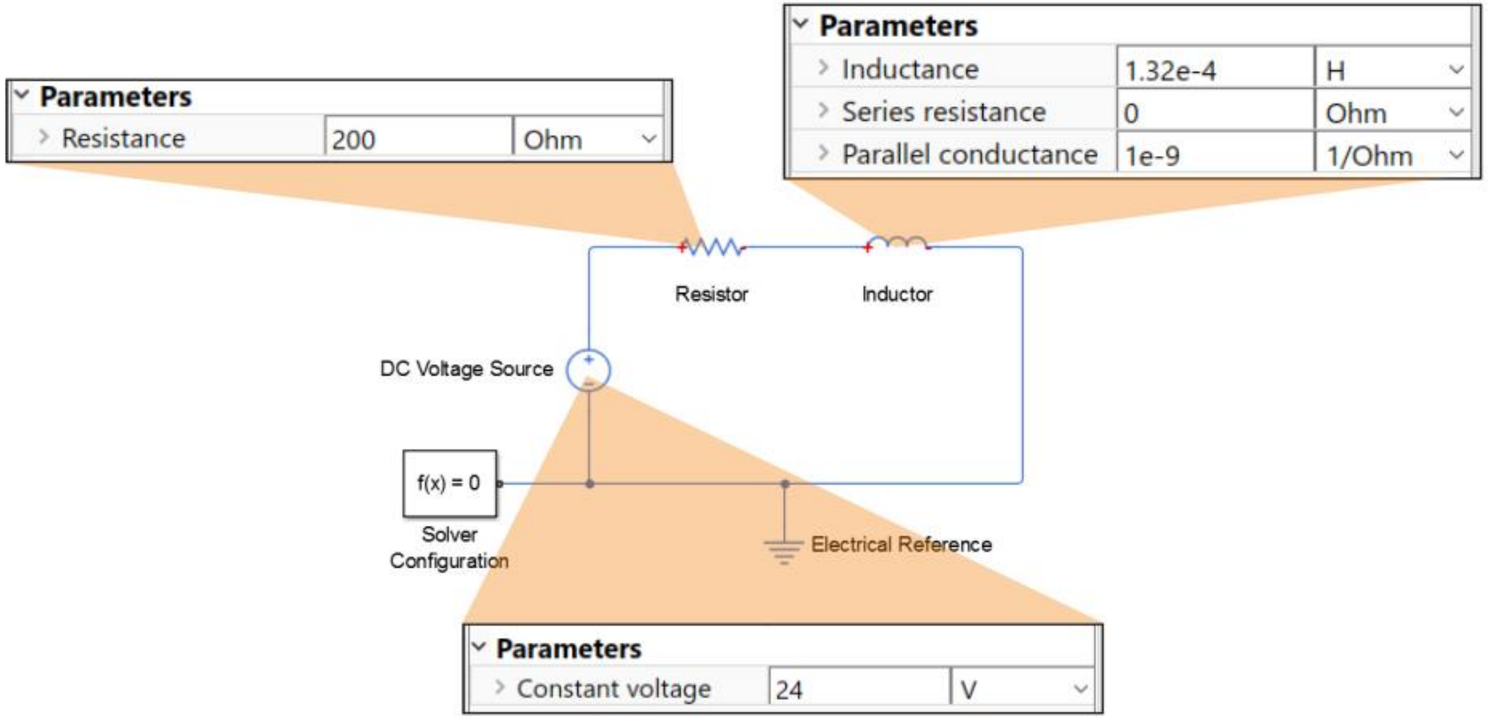




Parameters

Resistance	200	Ohm

Parameters

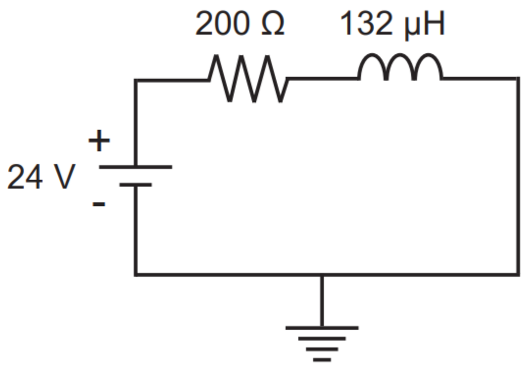
Inductance	1.32e-4	H
Series resistance	0	Ohm
Parallel conductance	1e-9	1/Ohm

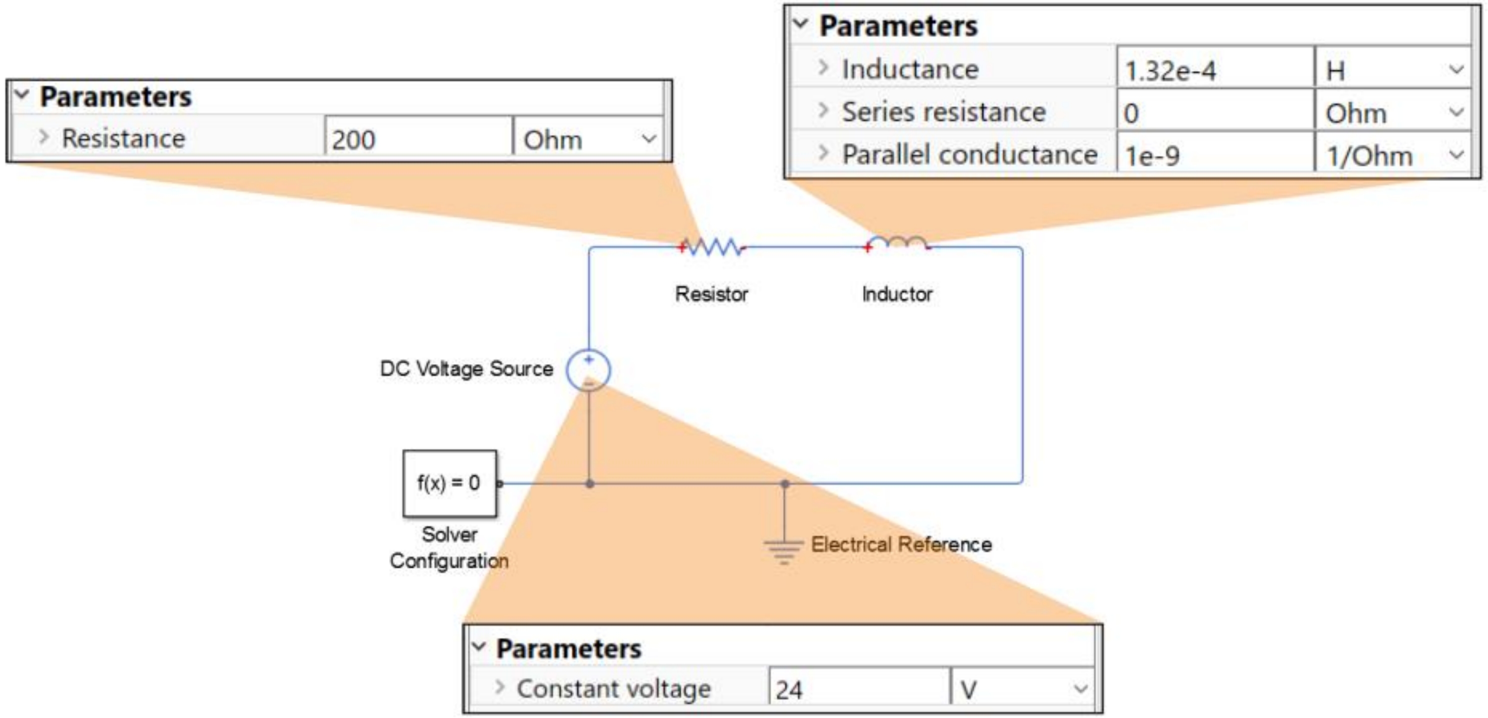
Parameters

Constant voltage	24	V

Setting block parameters

Simscape approach





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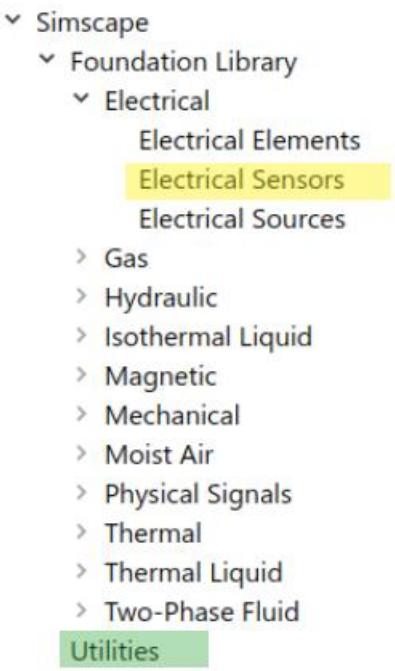

- Simscape
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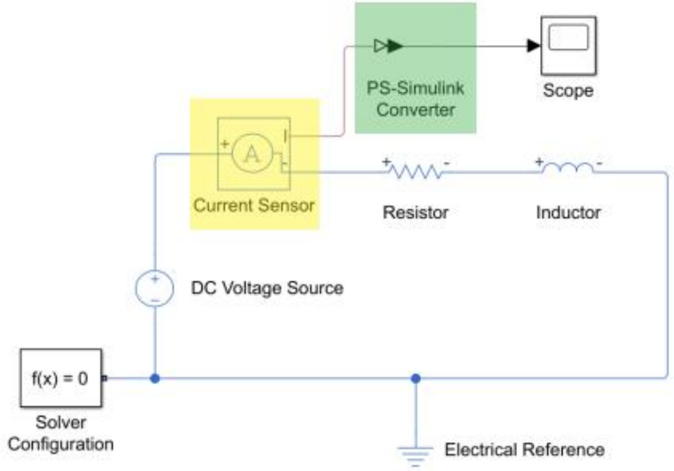
Simulink-PS Converter
PS-Simulink Converter

Blocks to interface Simulink and physical signals

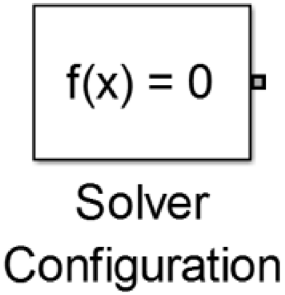


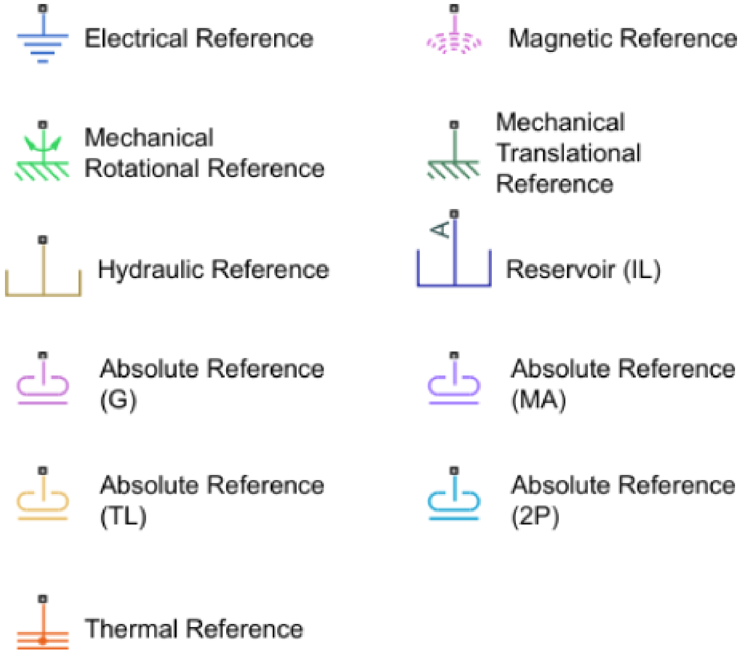
Connect with Simulink interface

Simscape approach

Solver Configuration block

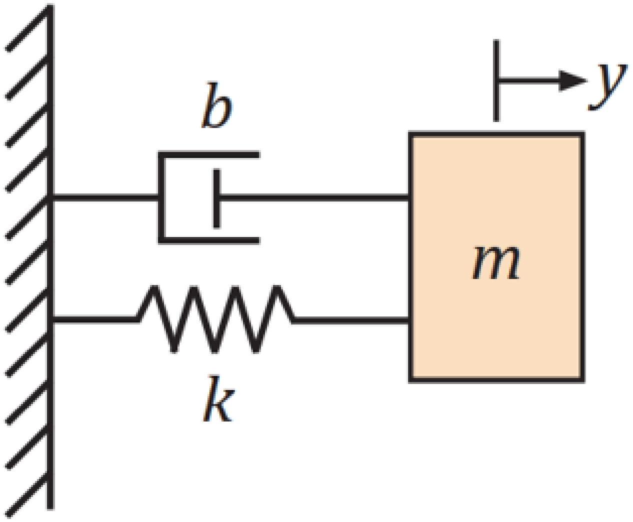
Domain-specific reference block



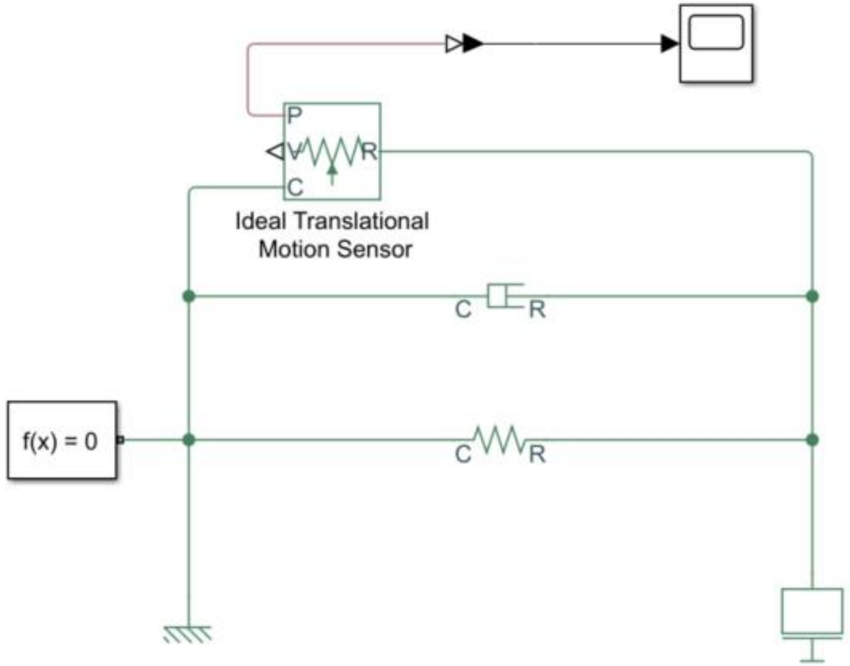


Simscape important Block

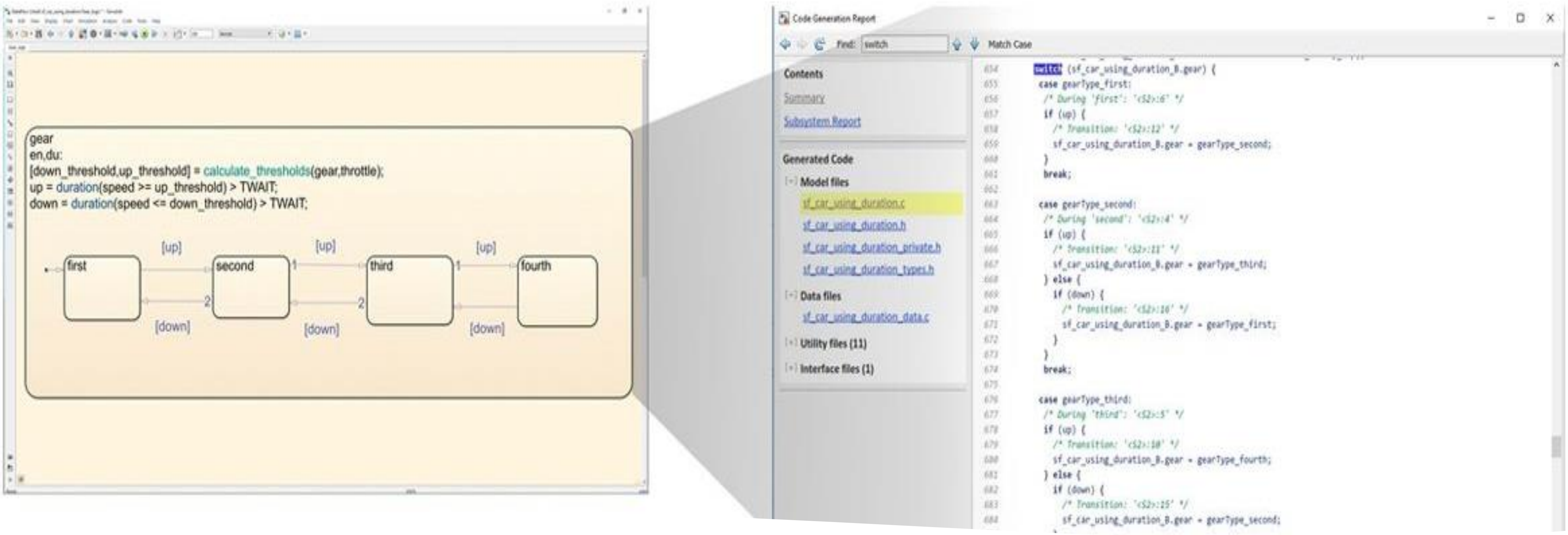
Simscape approach



Represented using diagram



Let’s try to create this Simscape model



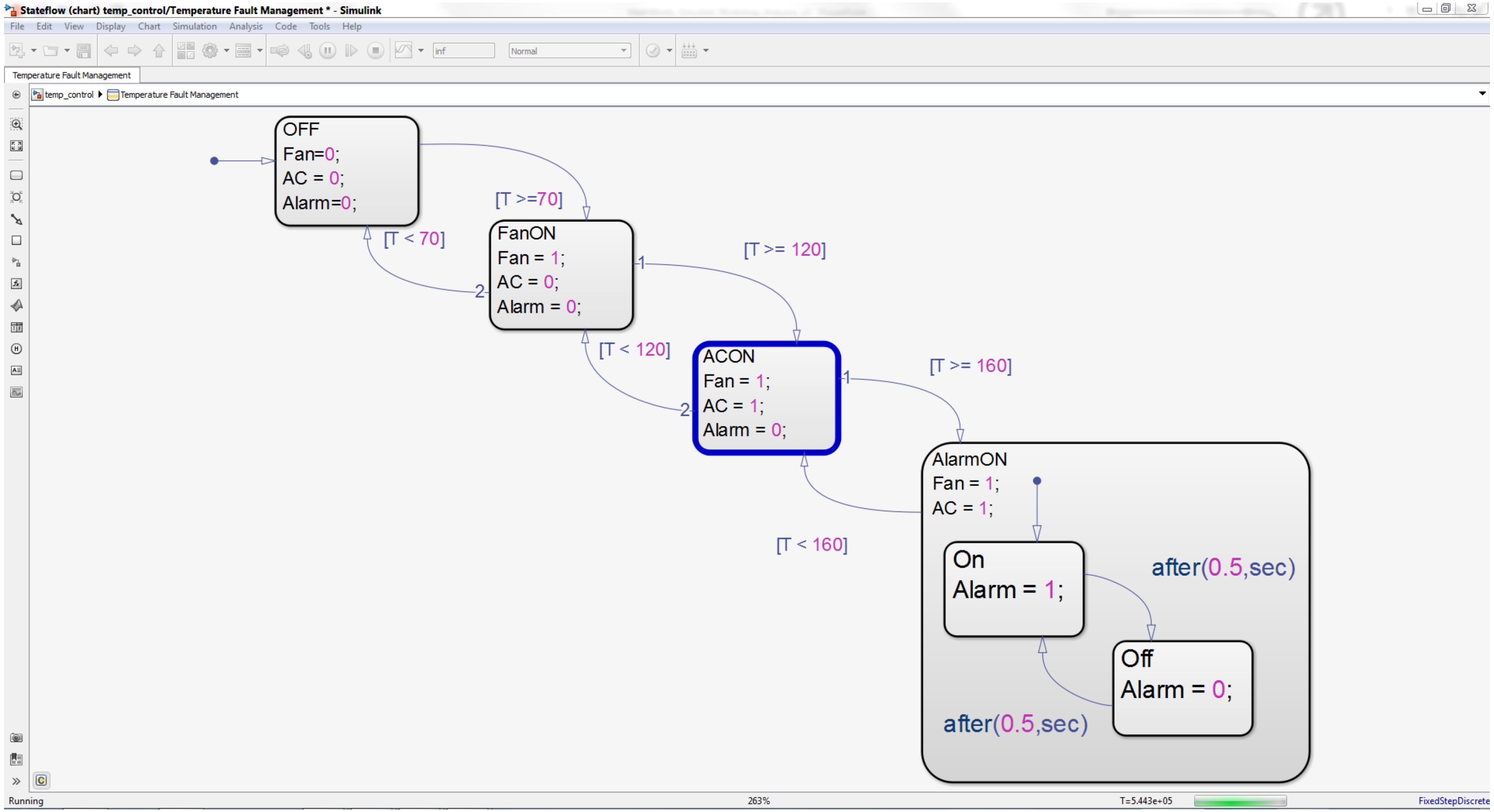
```
en,du:
[down_threshold,up_threshold] = calculate_thresholds(gear,throttle);
up = duration(speed >= up_threshold) > TWAIT;
down = duration(speed <= down_threshold) > TWAIT;
```

```
switch (sf_car_using_duration_B.gear) {
 case gearType_first:
  /* During 'first': '<S2>:6' */
  if (up) {
   /* Transition: '<S2>:12' */
   sf_car_using_duration_B.gear = gearType_second;
  }
  break;

 case gearType_second:
  /* During 'second': '<S2>:4' */
  if (up) {
   /* Transition: '<S2>:11' */
   sf_car_using_duration_B.gear = gearType_third;
  } else {
   if (down) {
    /* Transition: '<S2>:16' */
    sf_car_using_duration_B.gear = gearType_first;
   }
  }
  break;

 case gearType_third:
  /* During 'third': '<S2>:5' */
  if (up) {
   /* Transition: '<S2>:10' */
   sf_car_using_duration_B.gear = gearType_fourth;
  } else {
   if (down) {
    /* Transition: '<S2>:15' */
    sf_car_using_duration_B.gear = gearType_second;
```

Stateflow for Logic Driven Modeling

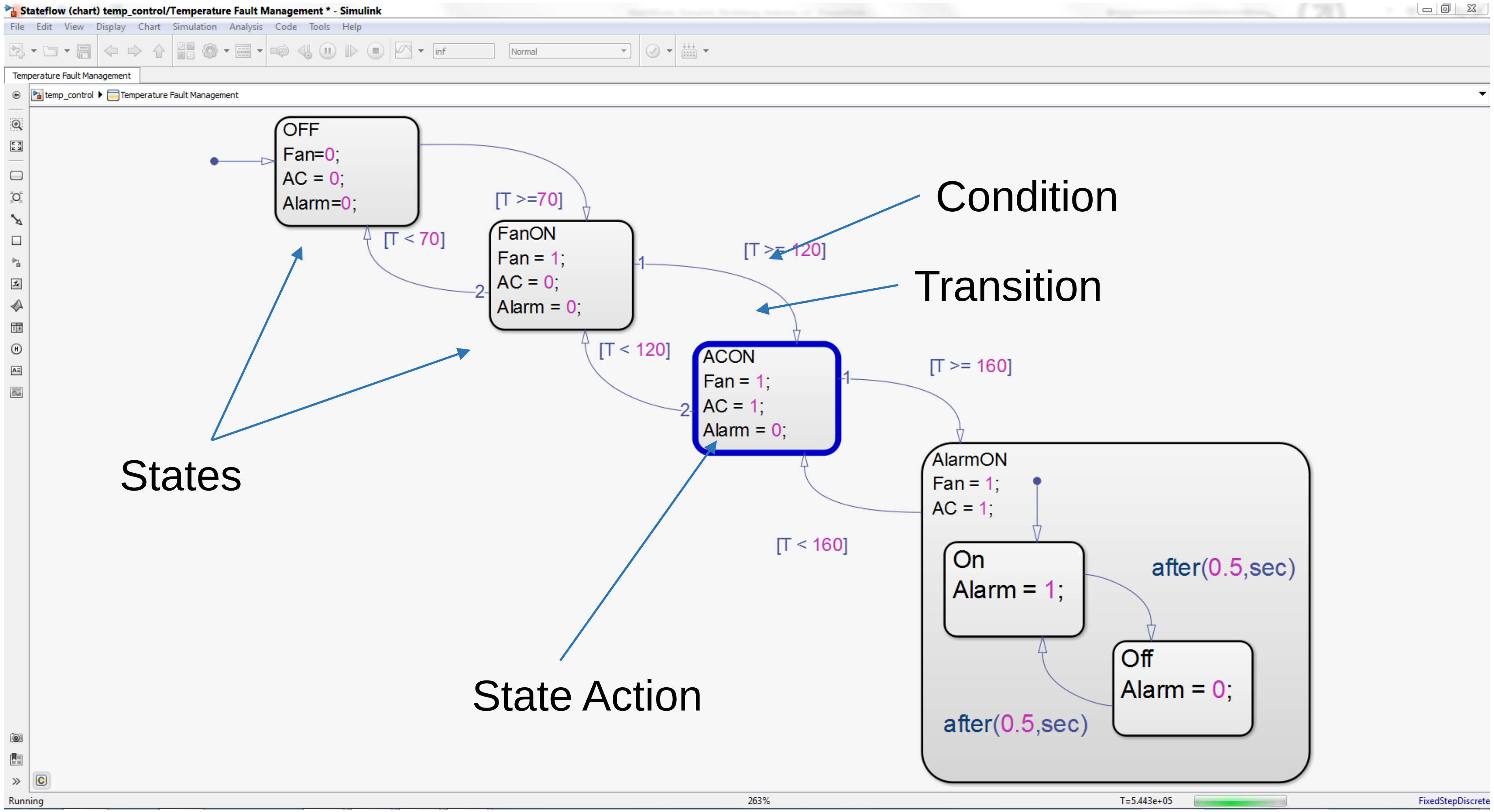
- Graphical language that includes state transition diagrams, flow charts, state transition tables, and truth tables.
- Describe how MATLAB® algorithms and Simulink® models react to input signals, events, and time-based conditions

Temperature Control logic using Stateflow



Stateflow (chart) temp_control/Temperature Fault Management * - Simulink

Temperature Control logic using Stateflow



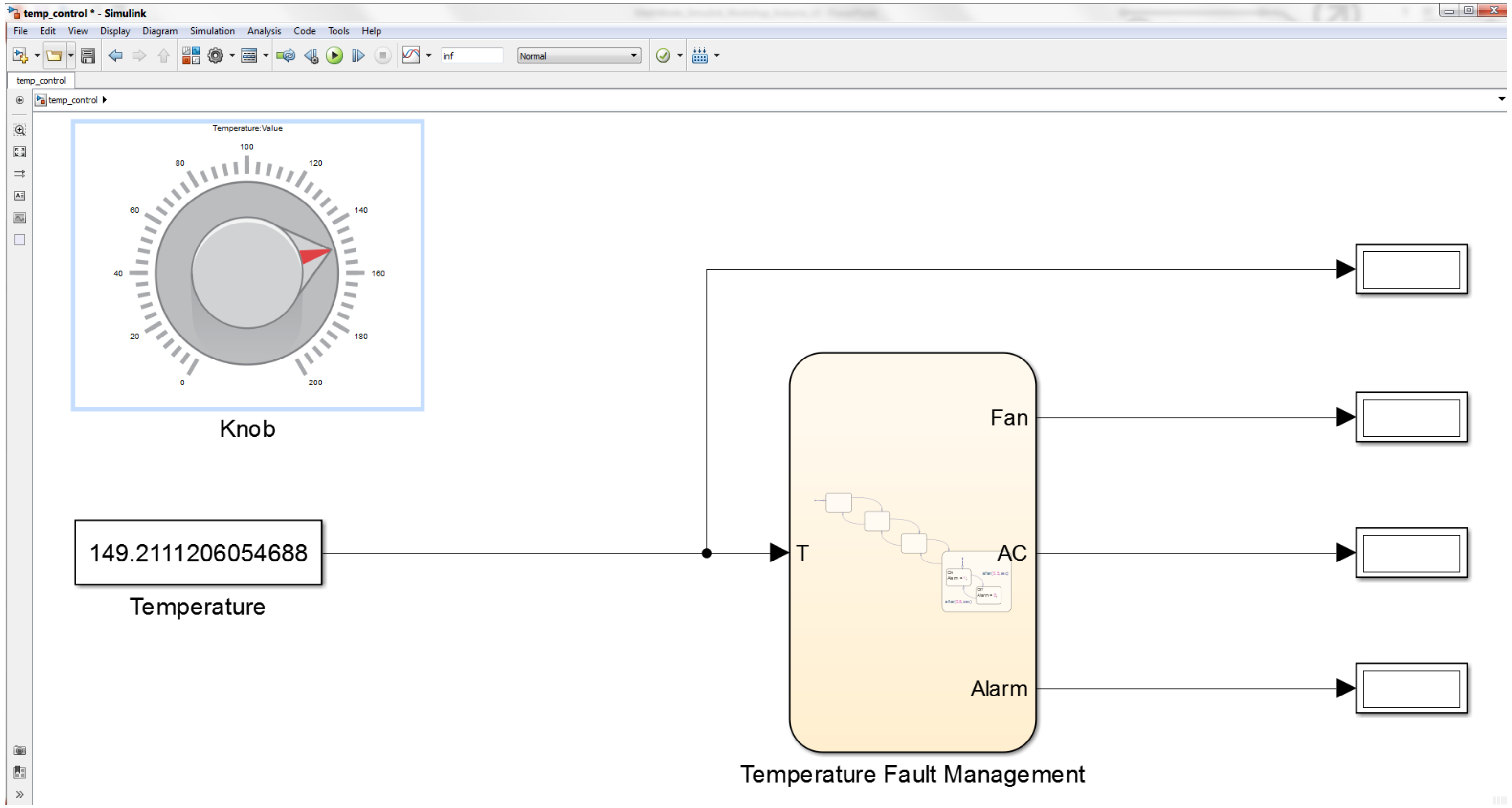
Condition

Transition

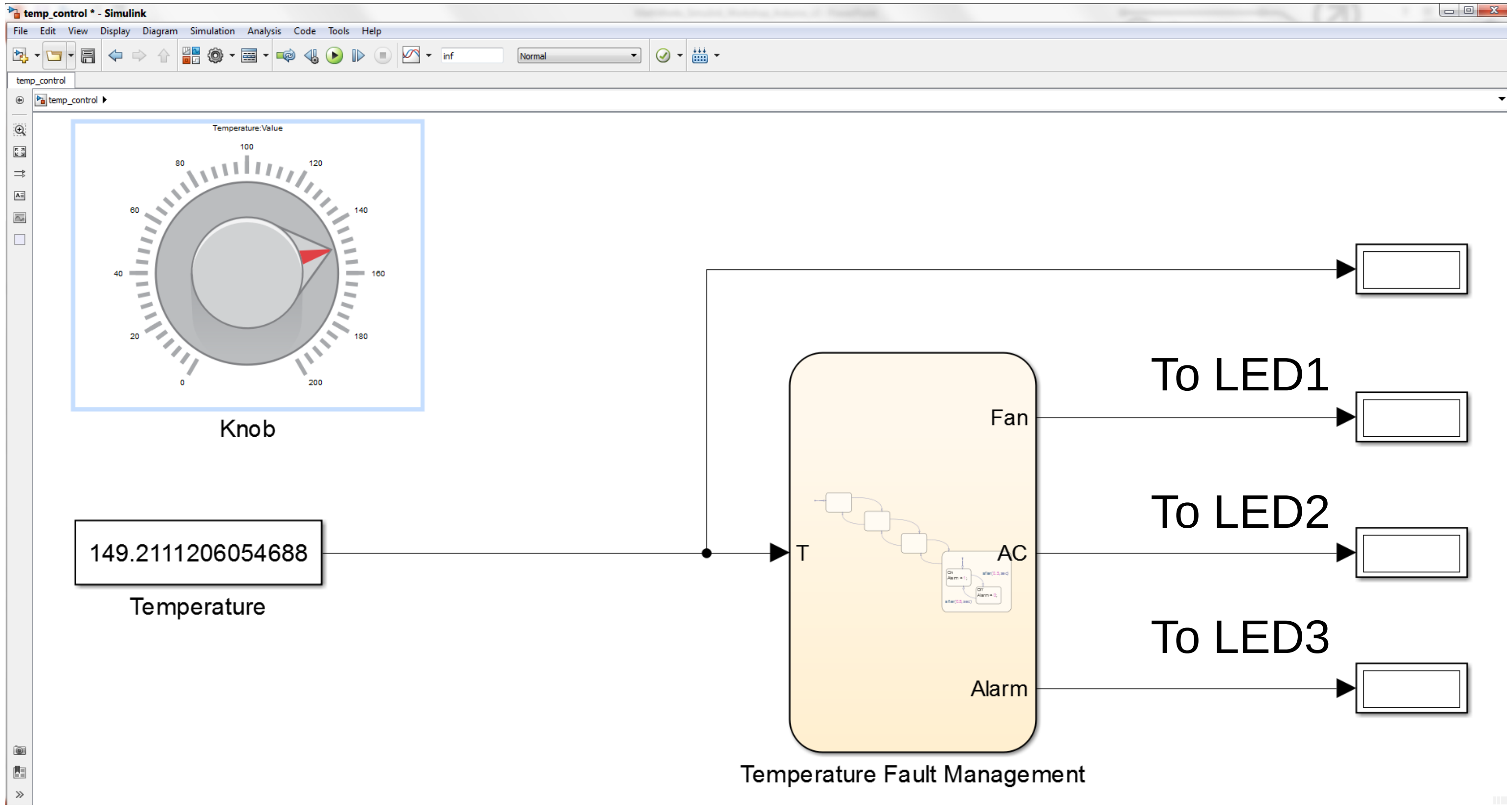
States

State Action

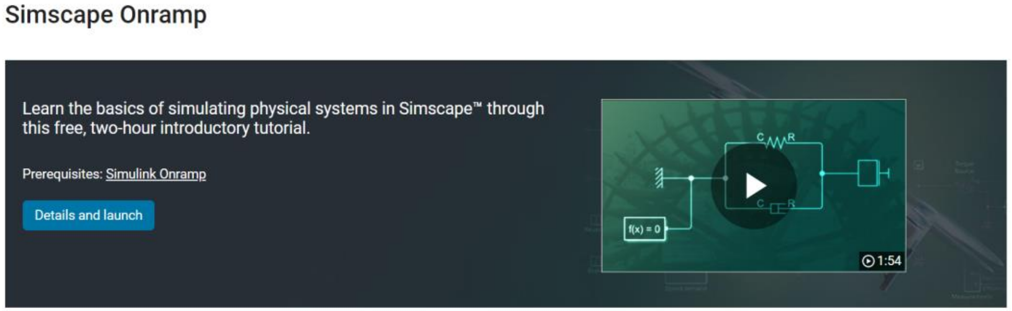
Temperature Control logic using Stateflow



Temperature Control logic using Stateflow



Simscape and Stateflow Onramp



Simscape Onramp

Learn the basics of simulating physical systems in Simscape™ through this free, two-hour introductory tutorial.

Prerequisites: Simulink Onramp

Stateflow Onramp

Learn the basics of how to create, edit, and simulate state machines in Stateflow® with this free interactive tutorial.

Prerequisites: MATLAB Onramp and Simulink Onramp

Upcoming session

- Overview of the basic BMS operation and functionality
- Simulink for BMS application covering:
    - Cell Voltage Measurement
    - SoC Main Operation
    - State of Health
    - Cell Voltage Balancing
- BMS Safety and Protection Function
- Step of development BMS with MBD until HW implementation including equipment required
- Commercial implementation and typical specification example

TECHSOURCE

ASCENDAS SYSTEMS

Thank you

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MATLAB® & SIMULINK®