Introduction of MATLAB and Simulink

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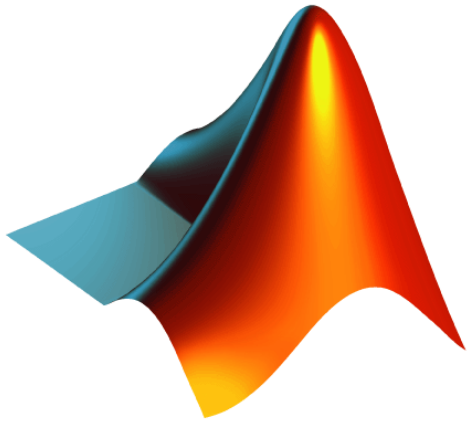


Outline

MATLAB and Simulink

Application

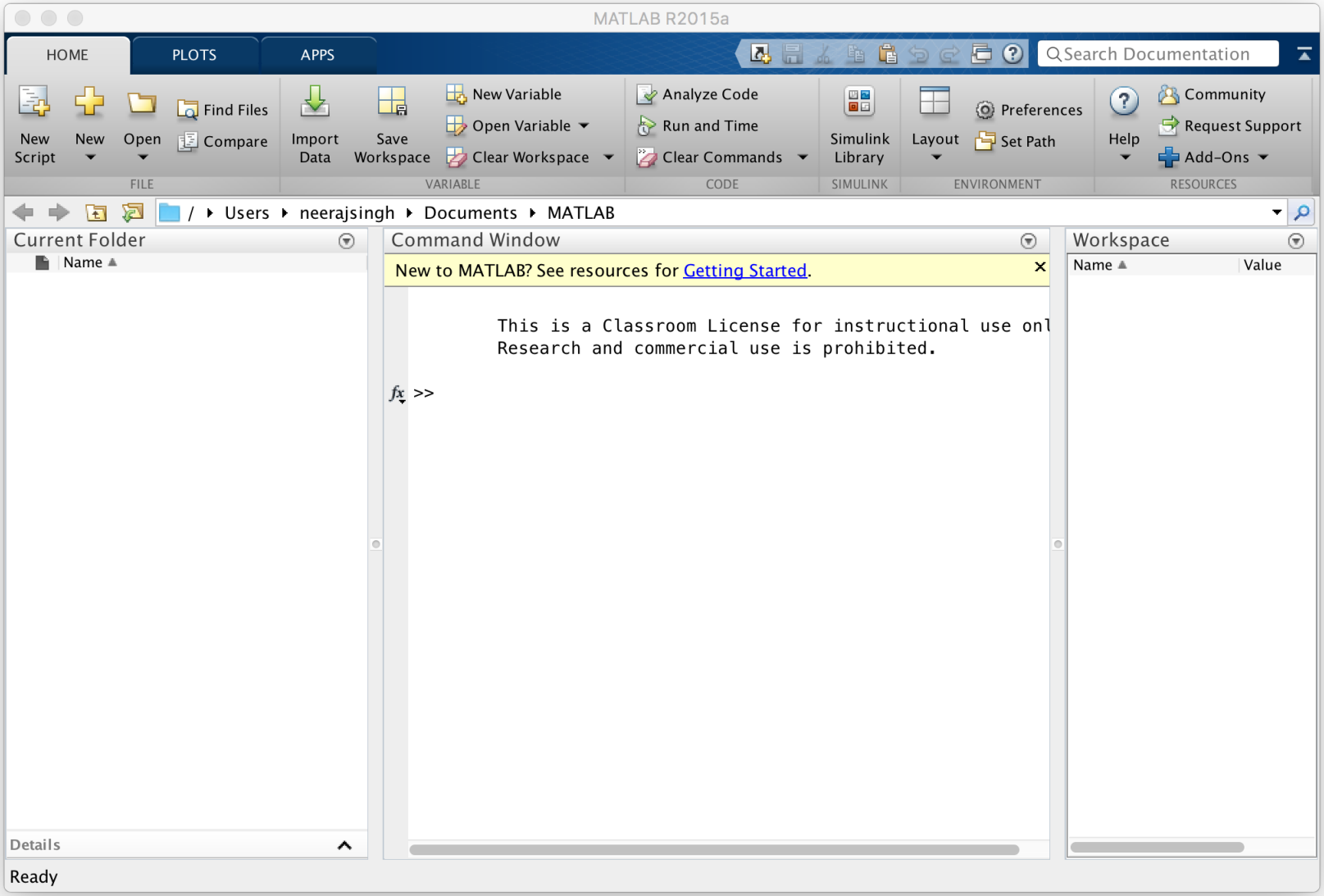
- Use of MATLAB and Simulink in Industry.

What is MATLAB?

- MATrix LABoratory
- Computational software
  - The MathWorks: www.mathworks.com
- Algorithm development environment
- Graphical modelling and simulation language
- Solving complex non-trivial mathematical operations, such as ODEs, root identification, and eigenvalue calculation
- Domain specific toolboxes and blocksets
- Alternative software
  - SciLab http://www.scilab.org/
  - GNU Octave http://www.gnu.org/software/octave/

MATLAB Interface

(1) Workspace (2) Current Directory
(3) Command History (4) Command Window

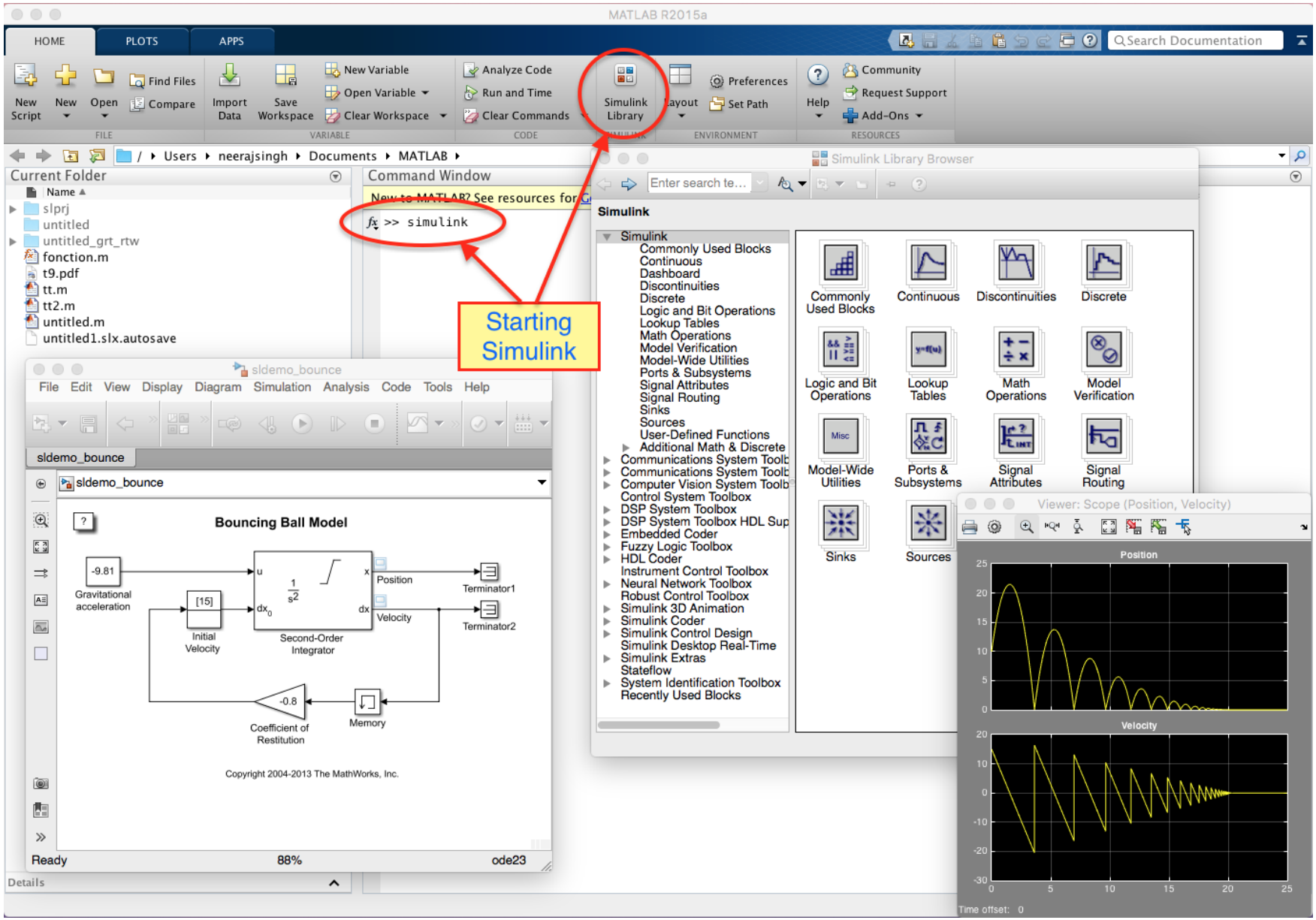


Simulink

What is Simulink?

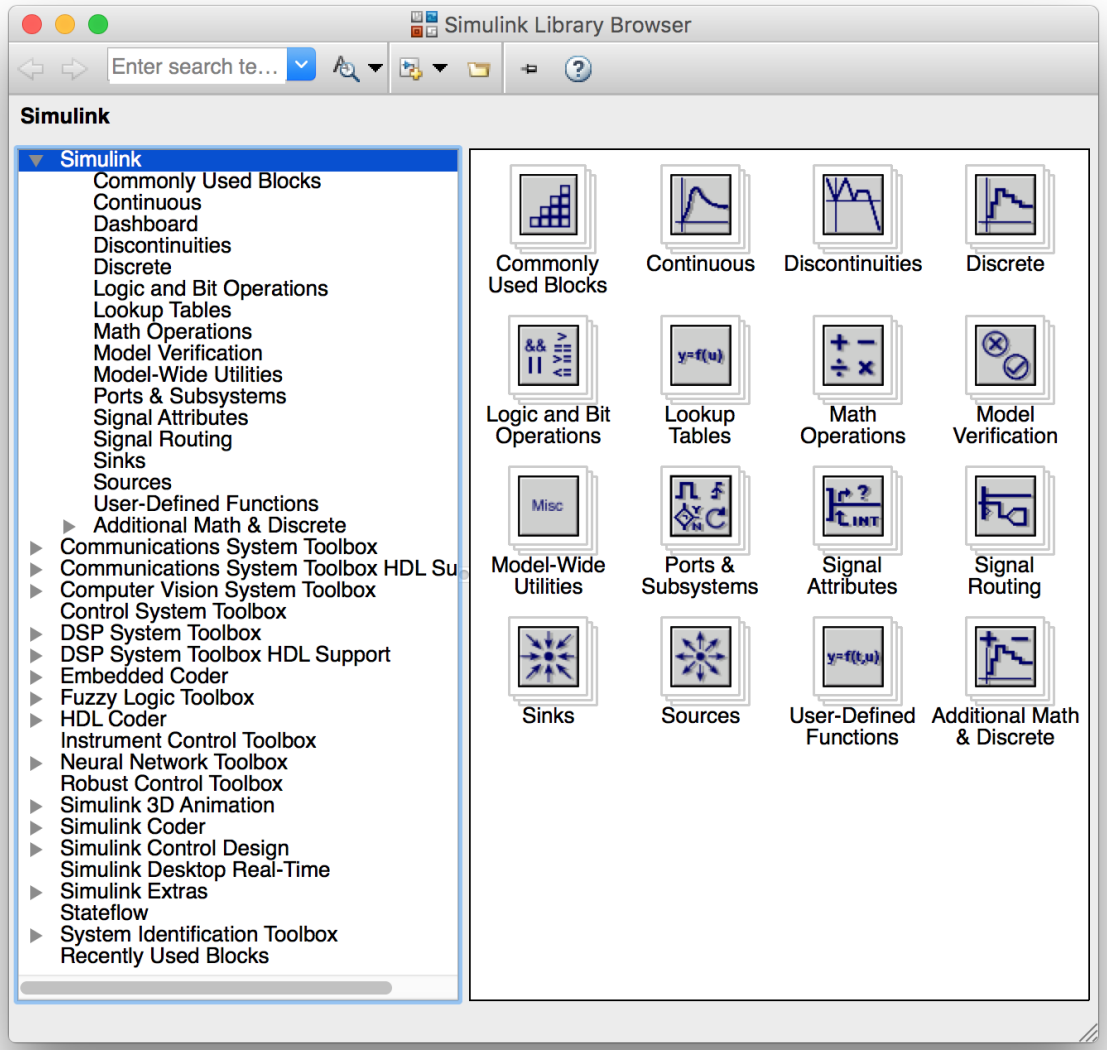
- Block based system modelling and simulation
- A collection of standard toolboxes and libraries (Machine learning, signal processing, image processing etc.)
- Direct interaction with hardware and real-time systems
- Multi-domain modelling using signal flow diagrams, state machines and physical modelling
- Heterogeneous programming environment (such as C, C++ and FORTRAN) using S-Function blocks
- Automatic code generation for deployment

Launching Simulink

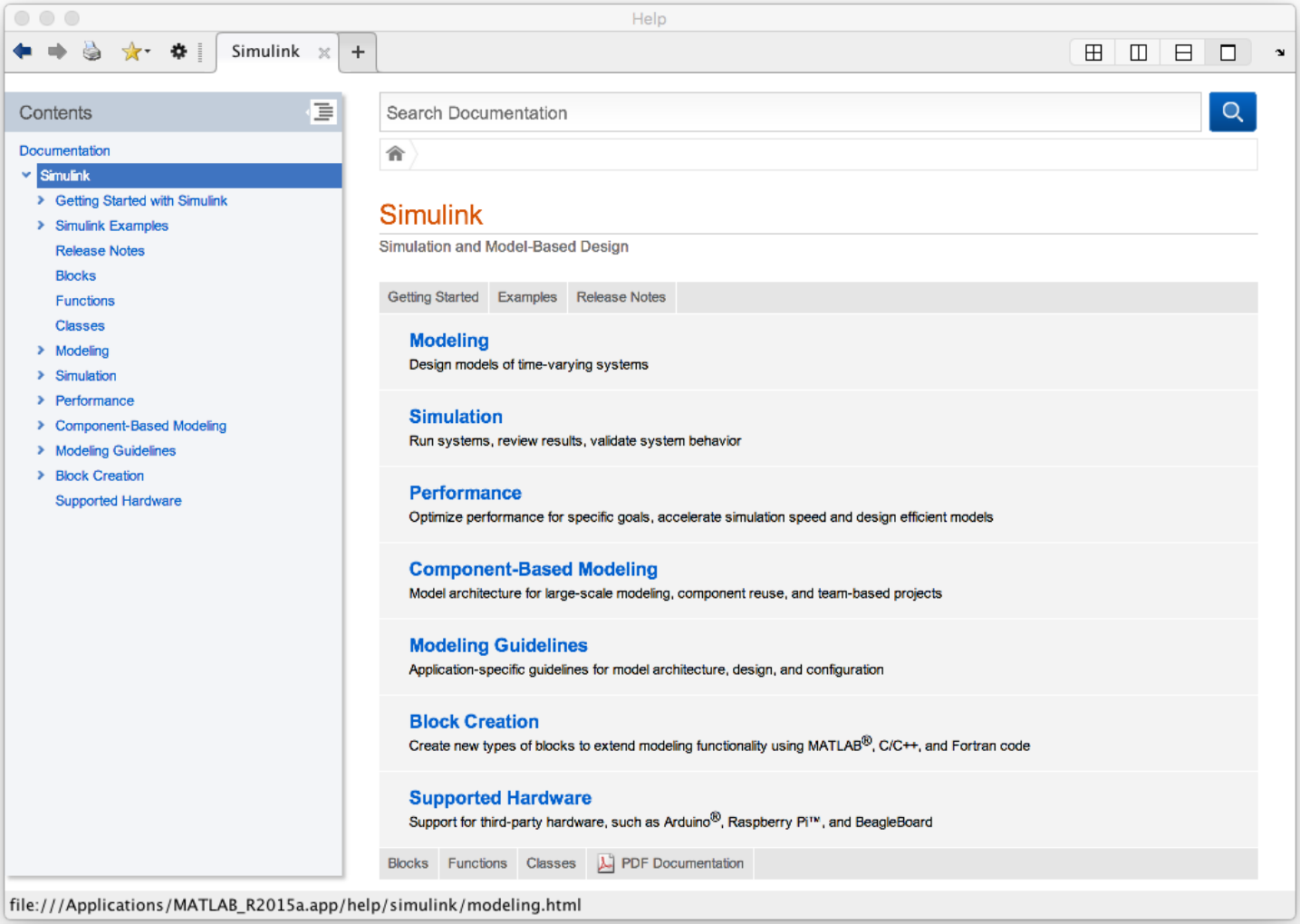


Simulink Library Browser

(1) Search Block (2) Block List
(3) New Simulink Model (4) Help

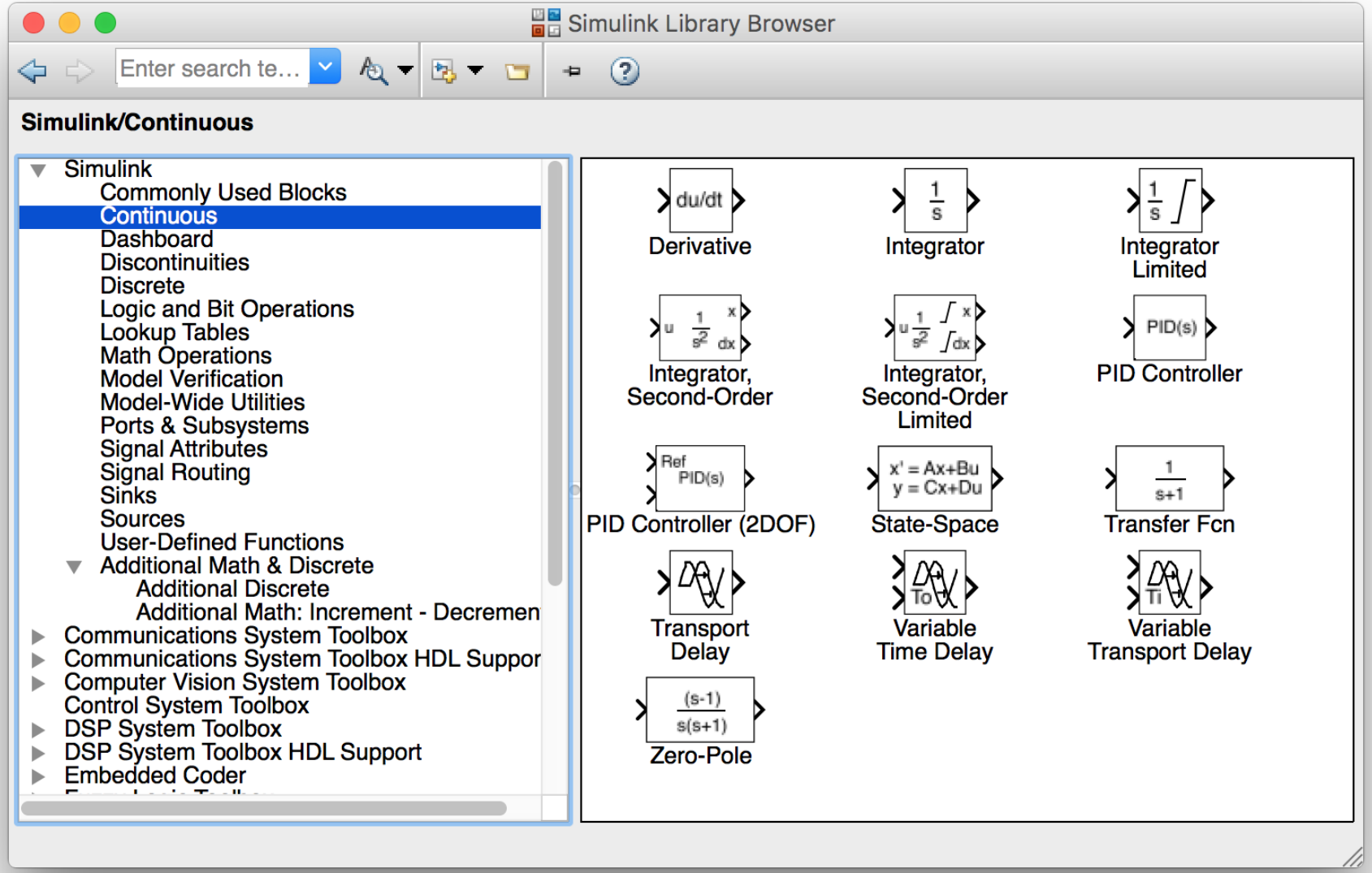


Simulink Help

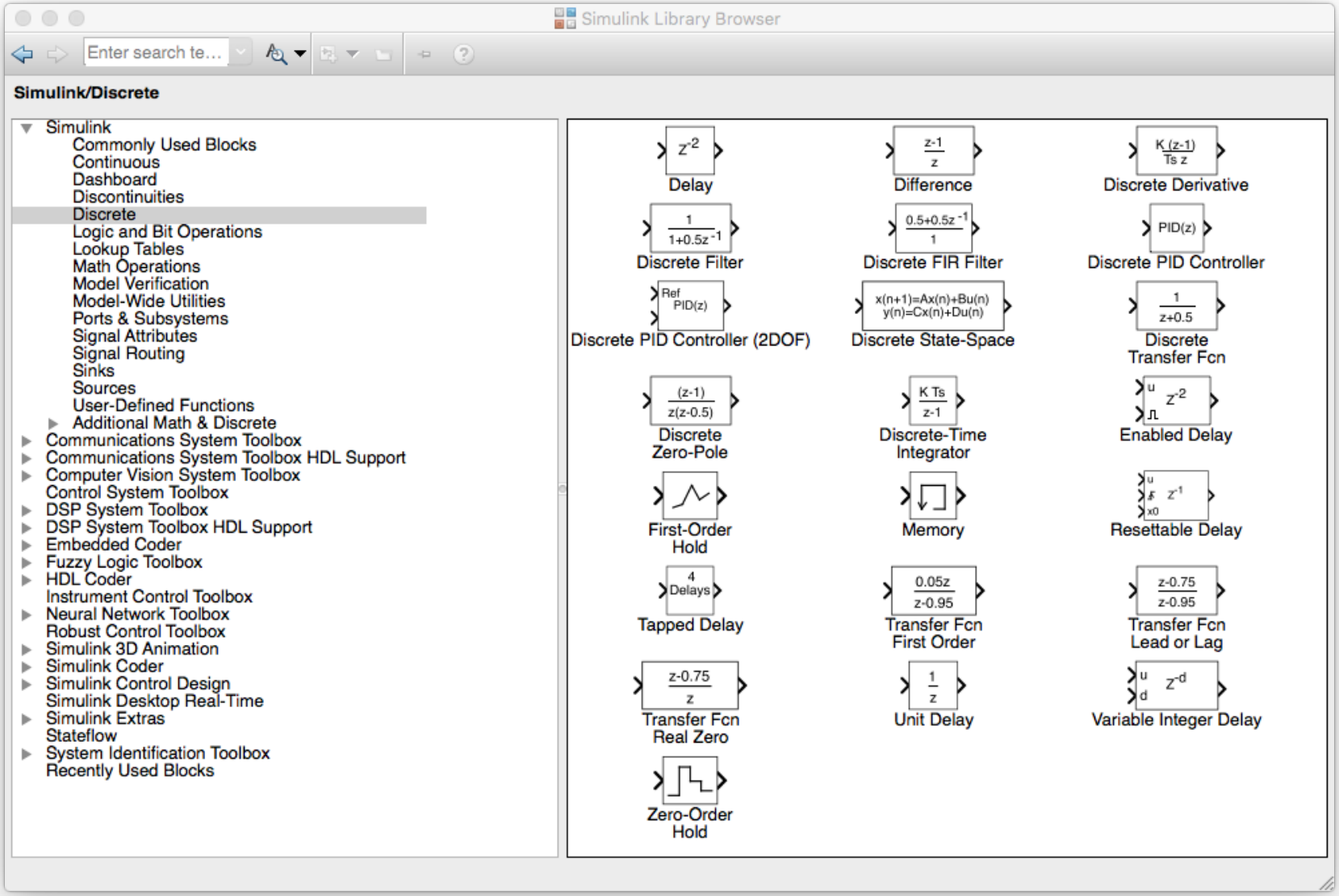


Use the "Help" button in the library browser for finding tutorials, demos, information on available blocks, and so on.

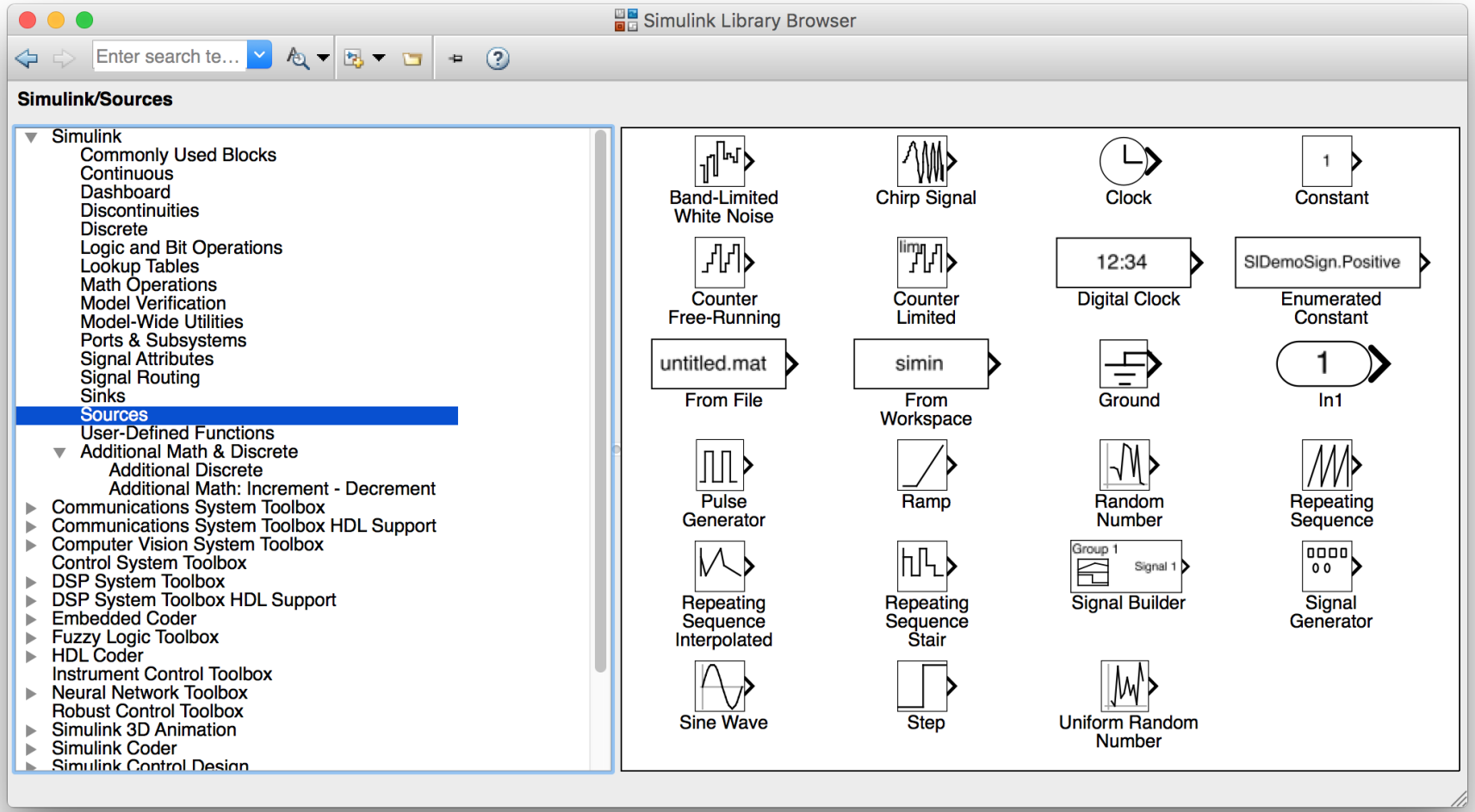
Continuous Blocks



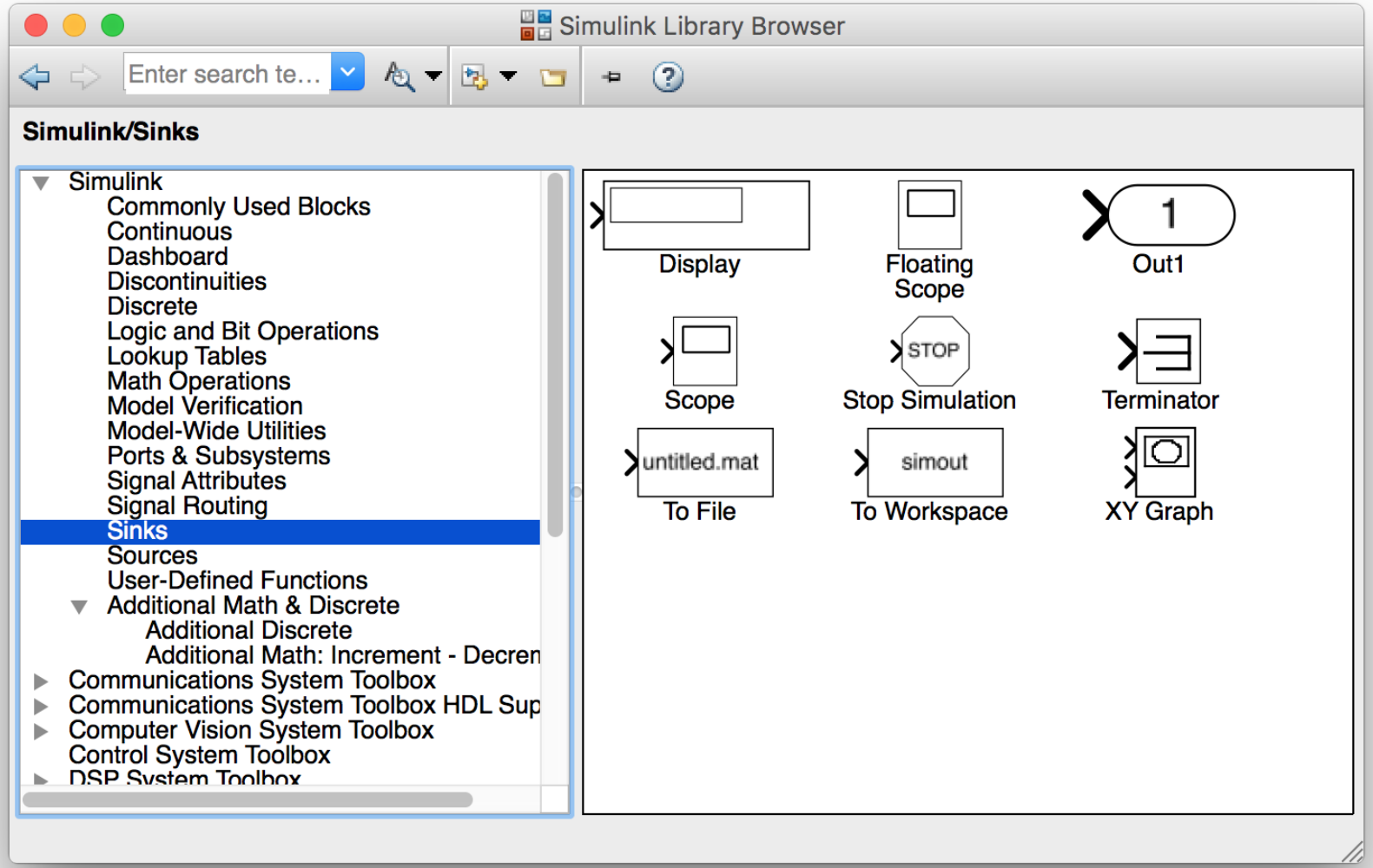
Discrete Blocks



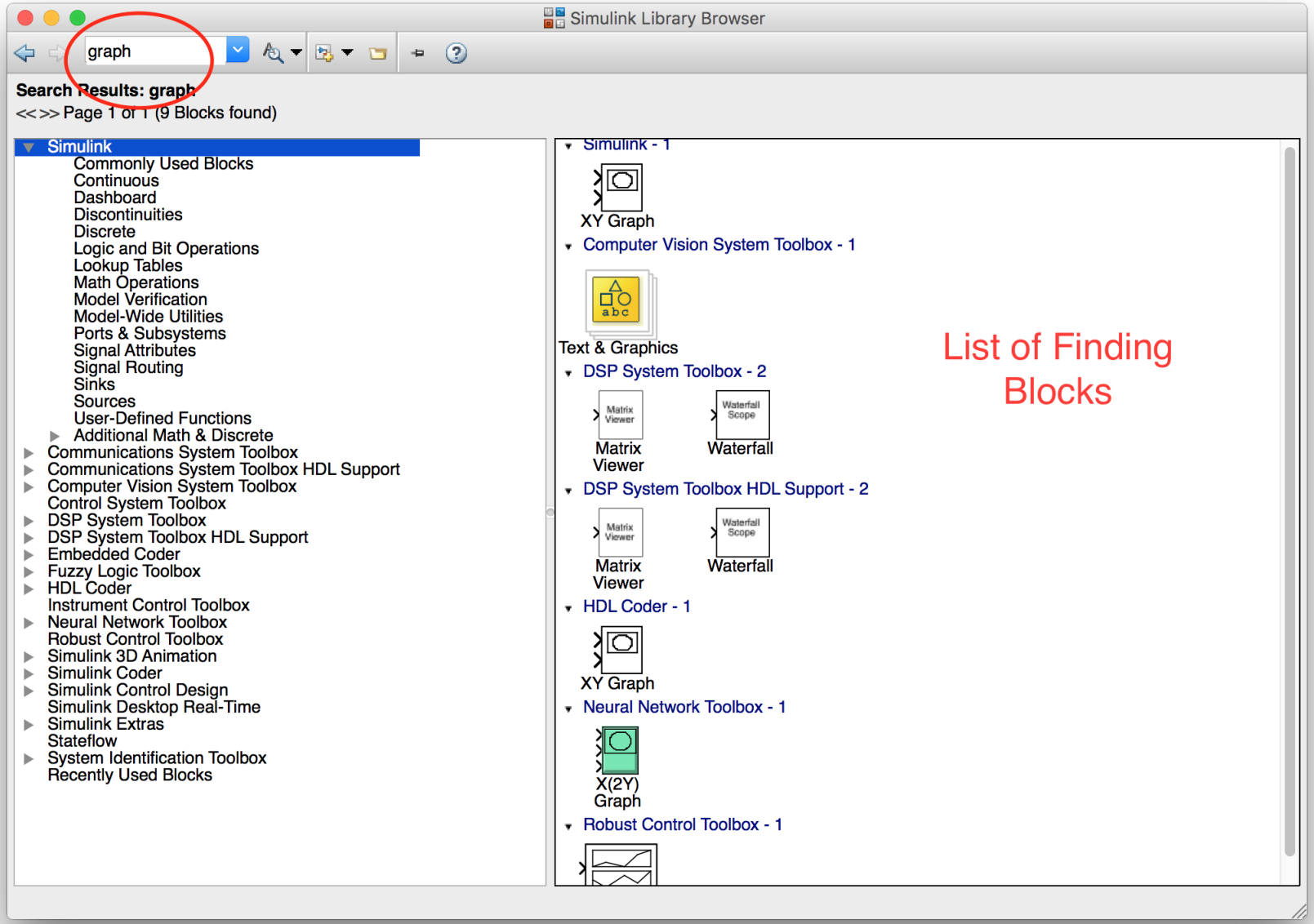
Source Blocks



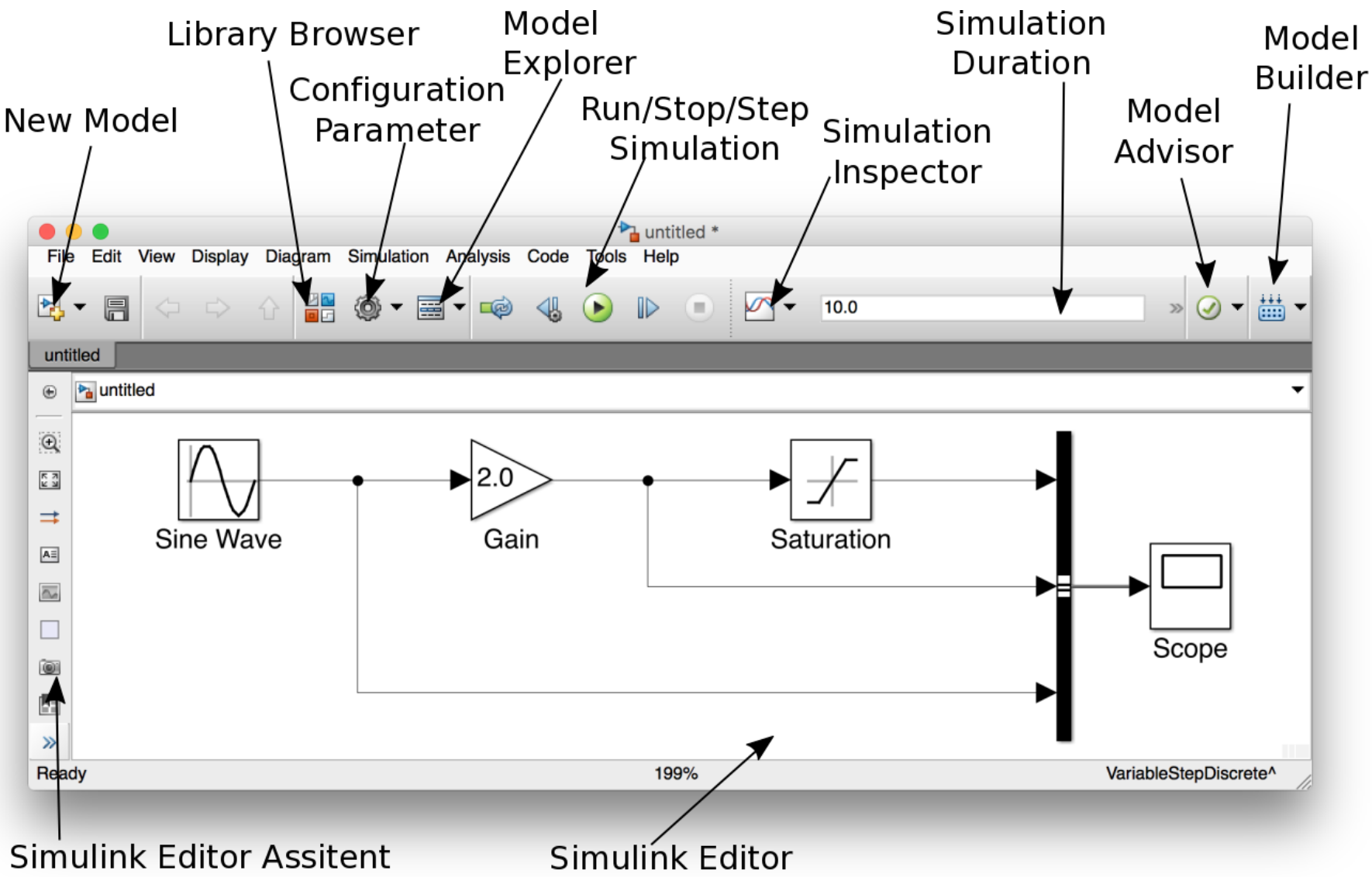
Sink Blocks


Simulink Library Browser
Enter search te...
Simulink/Sinks
Simulink
Commonly Used Blocks
Continuous
Dashboard
Discontinuities
Discrete
Logic and Bit Operations
Lookup Tables
Math Operations
Model Verification
Model-Wide Utilities
Ports & Subsystems
Signal Attributes
Signal Routing
Sinks
Sources
User-Defined Functions
Additional Math & Discrete
Additional Discrete
Additional Math: Increment - Decren
Communications System Toolbox
Communications System Toolbox HDL Sup
Computer Vision System Toolbox
Control System Toolbox
DSP System Toolbox
Display
Floating Scope
1
Out1
Scope
STOP
Stop Simulation
Terminator
untitled.mat
To File
simout
To Workspace
XY Graph

Finding Blocks



Simulink Window (Editor)



Importing and Exporting Data

Importing and Exporting Data

Importing Data into Simulink

- In
- Constant
- From Workspace
- From File

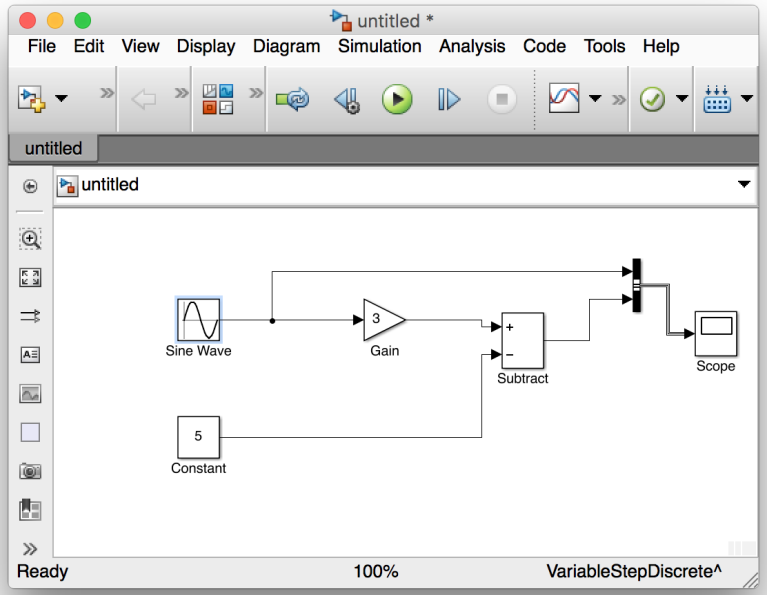
Exporting Data from Simulink

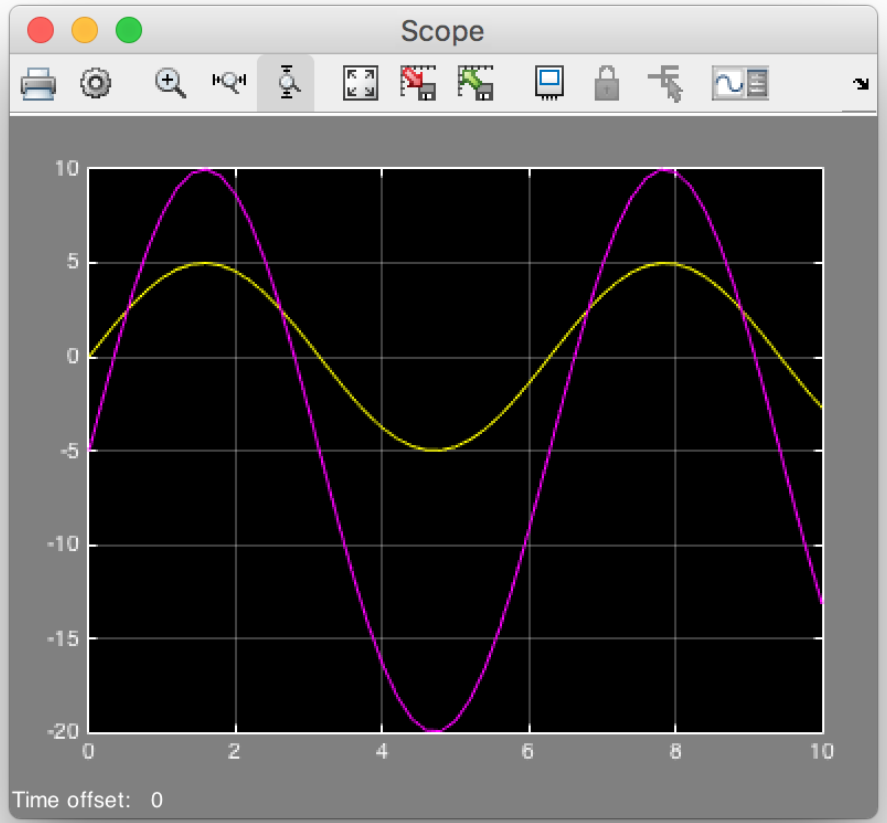
- Out
- To Workspace
- To File

System Modelling

System Modelling: Example

$$y = 3 * Sin(t) - 5$$

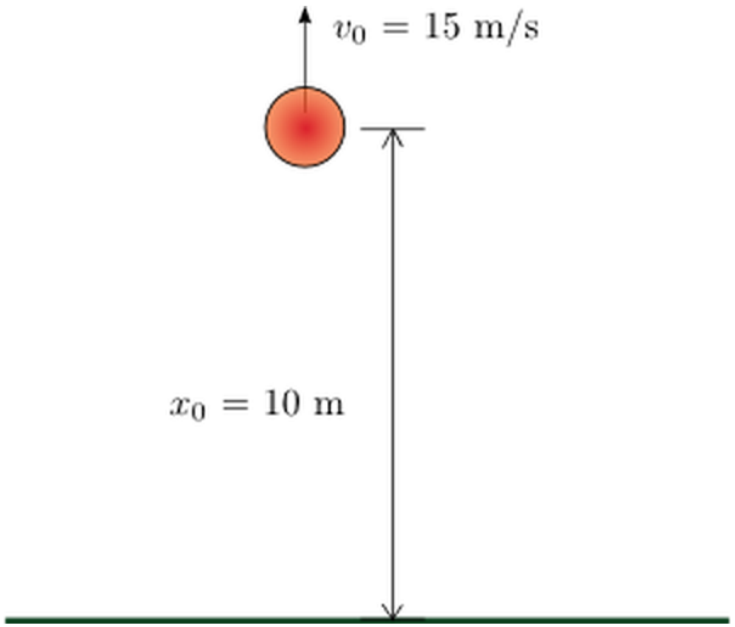




Continuous and Discrete Modelling

Continuous Systems

Modelling of a Bouncing Ball

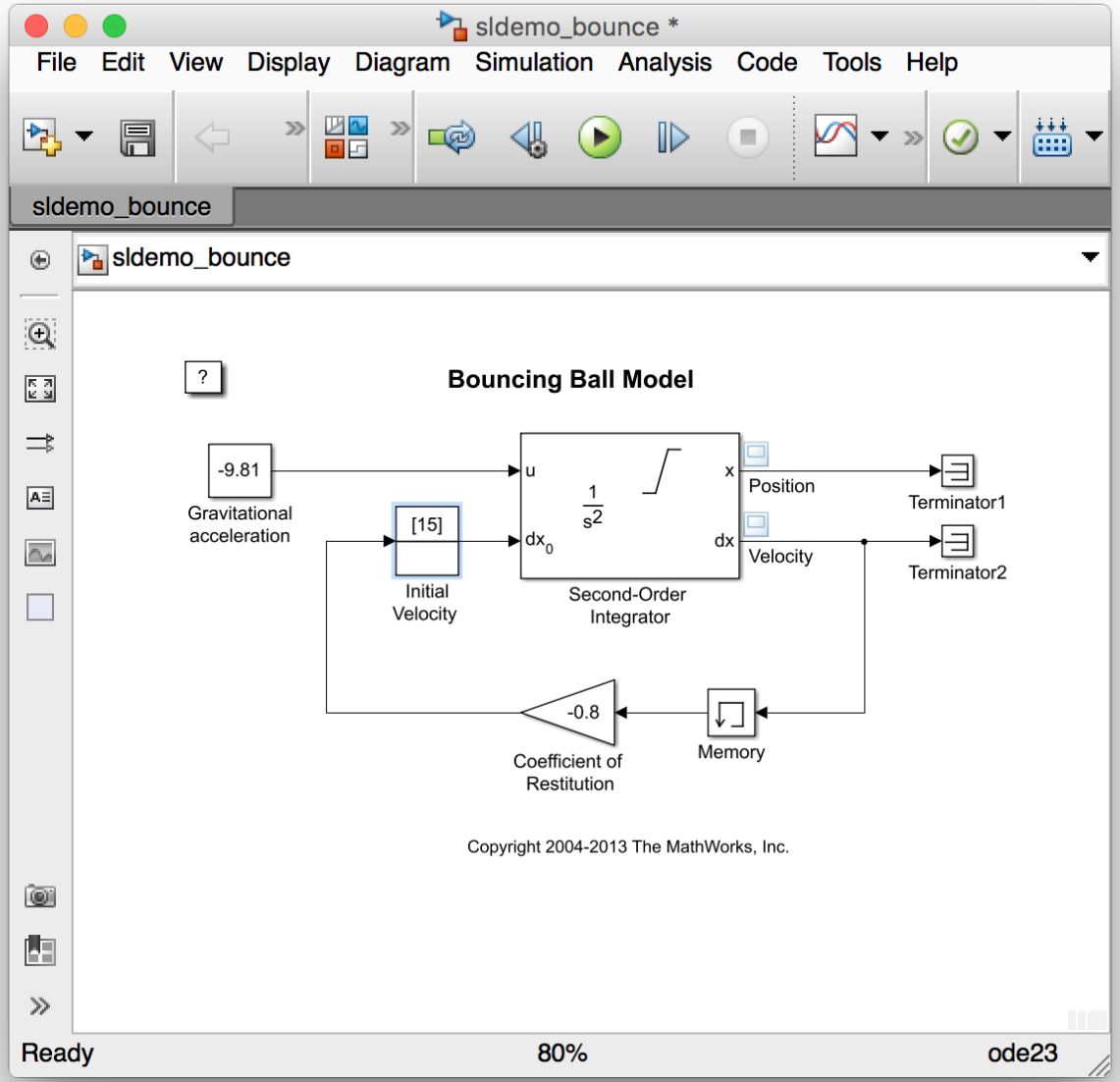


$$\frac{dx}{dt} = v \tag{1}$$

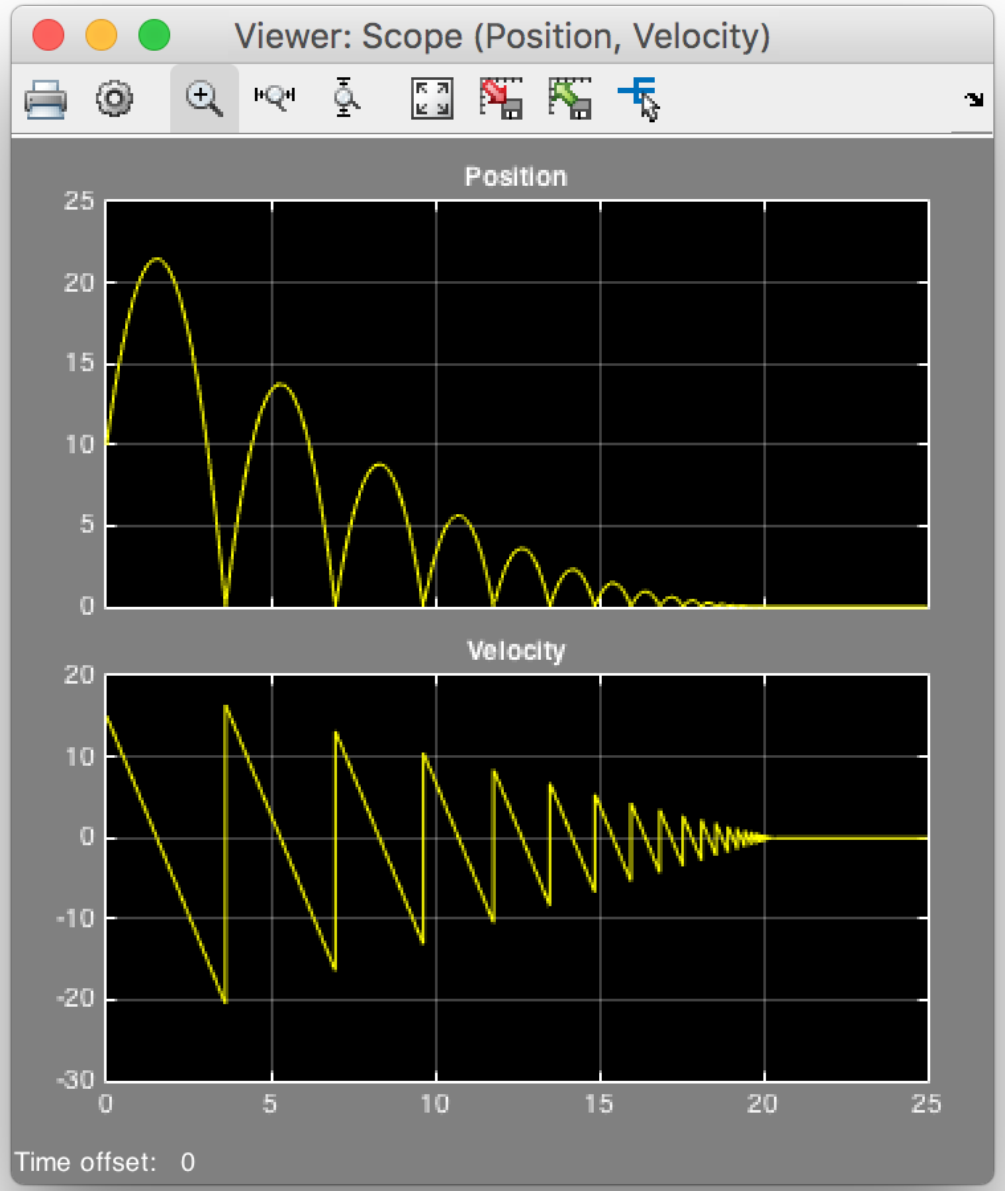
$$\frac{dv}{dt} = -g \tag{2}$$

Coefficient of restitution ($v^+ = K.v^-$)

Simulink Model of a Bouncing Ball



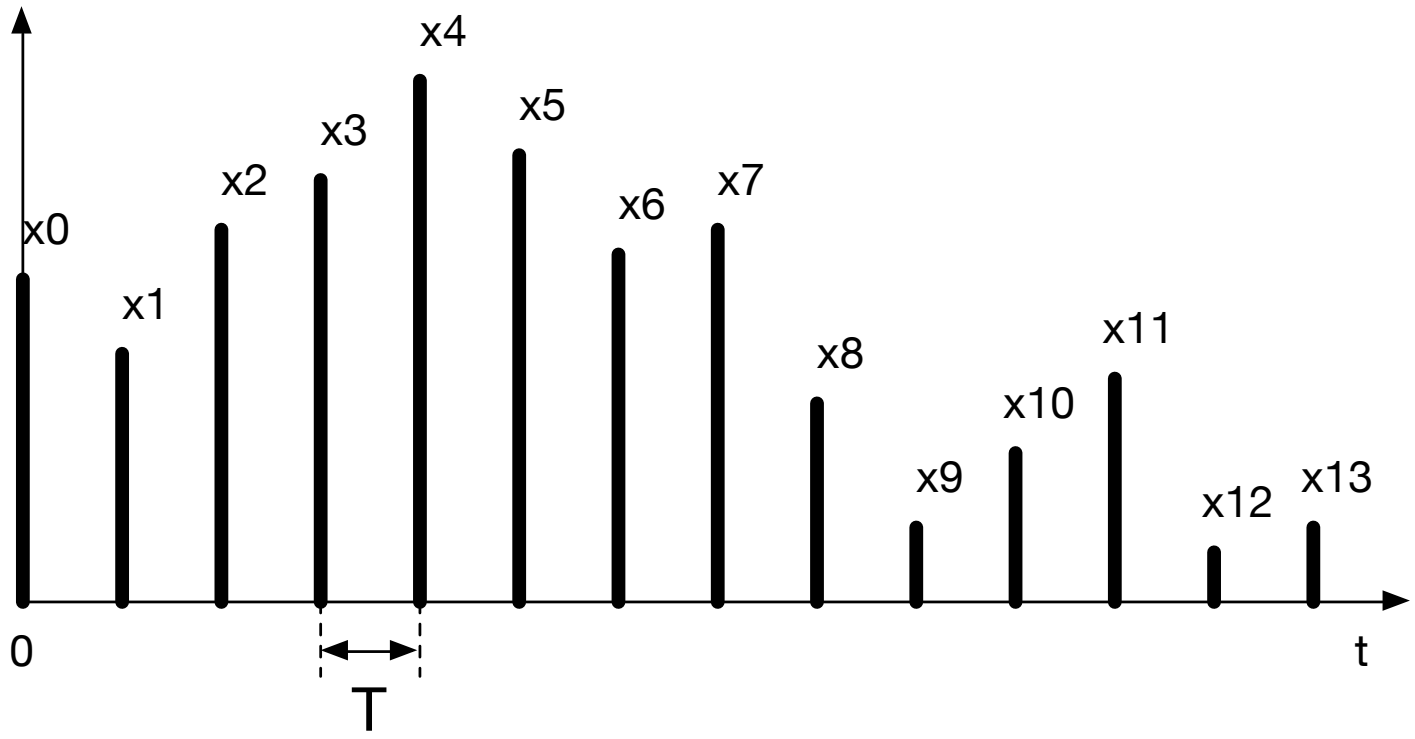
Simulation Results of a Bouncing Ball



Discrete Systems

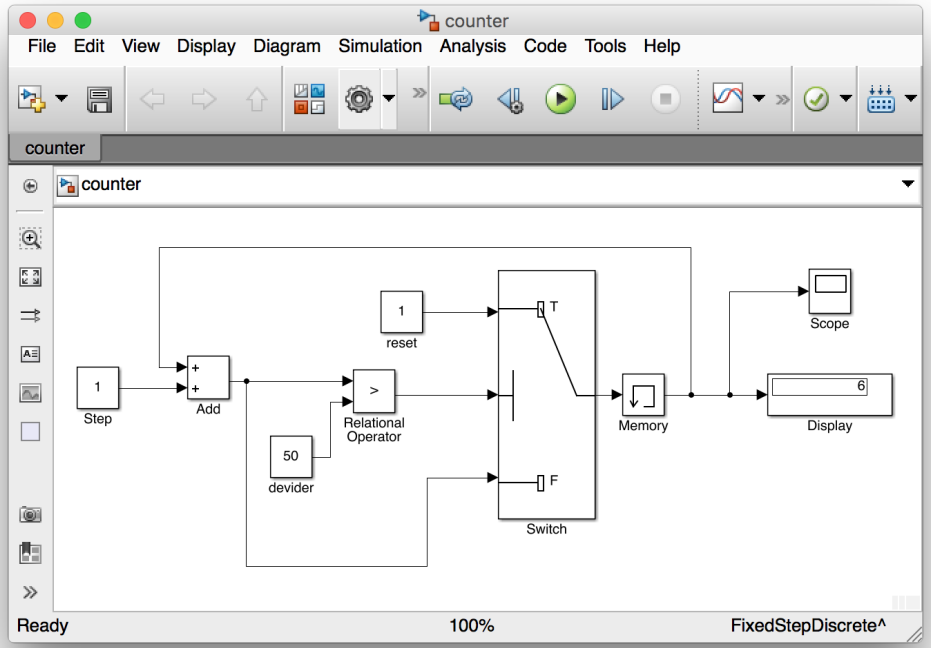
Discrete Systems

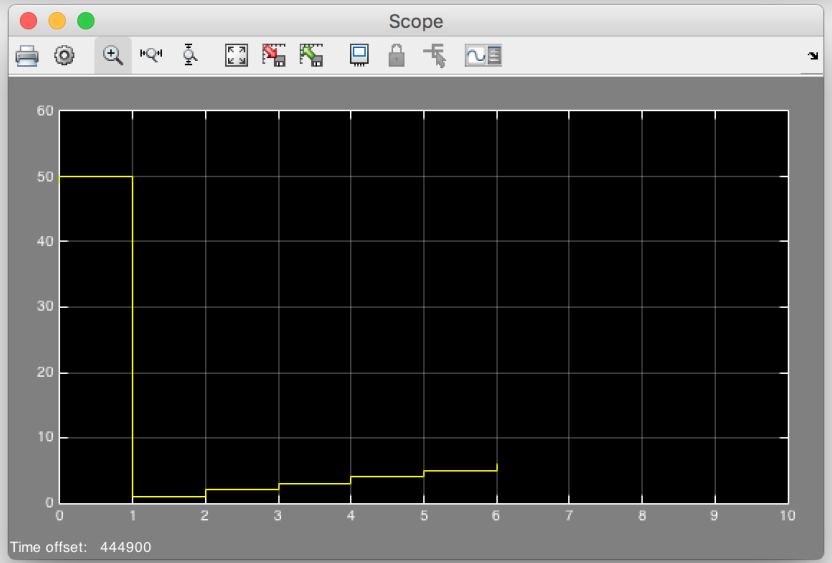
A discrete signal is a signal that has values only at discrete points in time.
A sampled signal is a discrete signal.



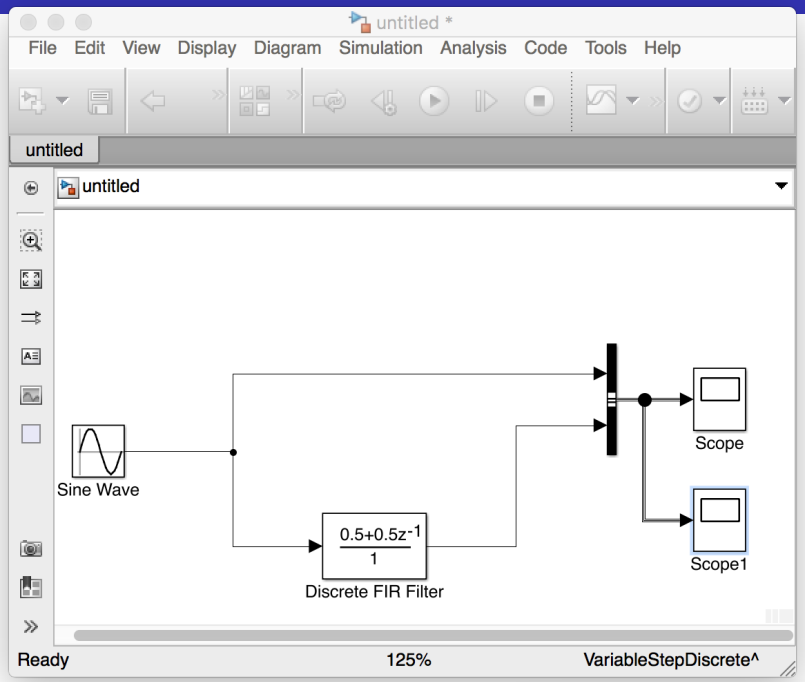
The sample period (T) is the time between two successive samples.

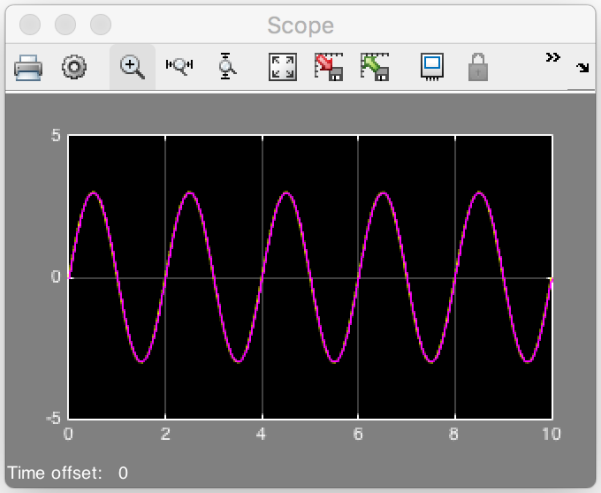
System Modelling: Digital Counter

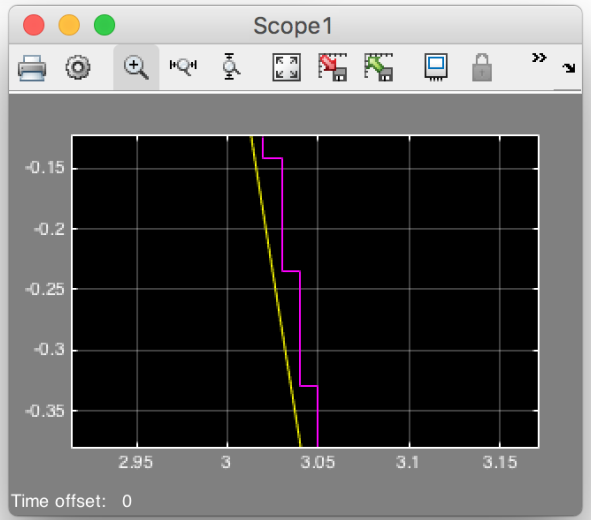




System Modelling: Example







Solver

- Determines solution at current time step
- Determines the next simulation time step

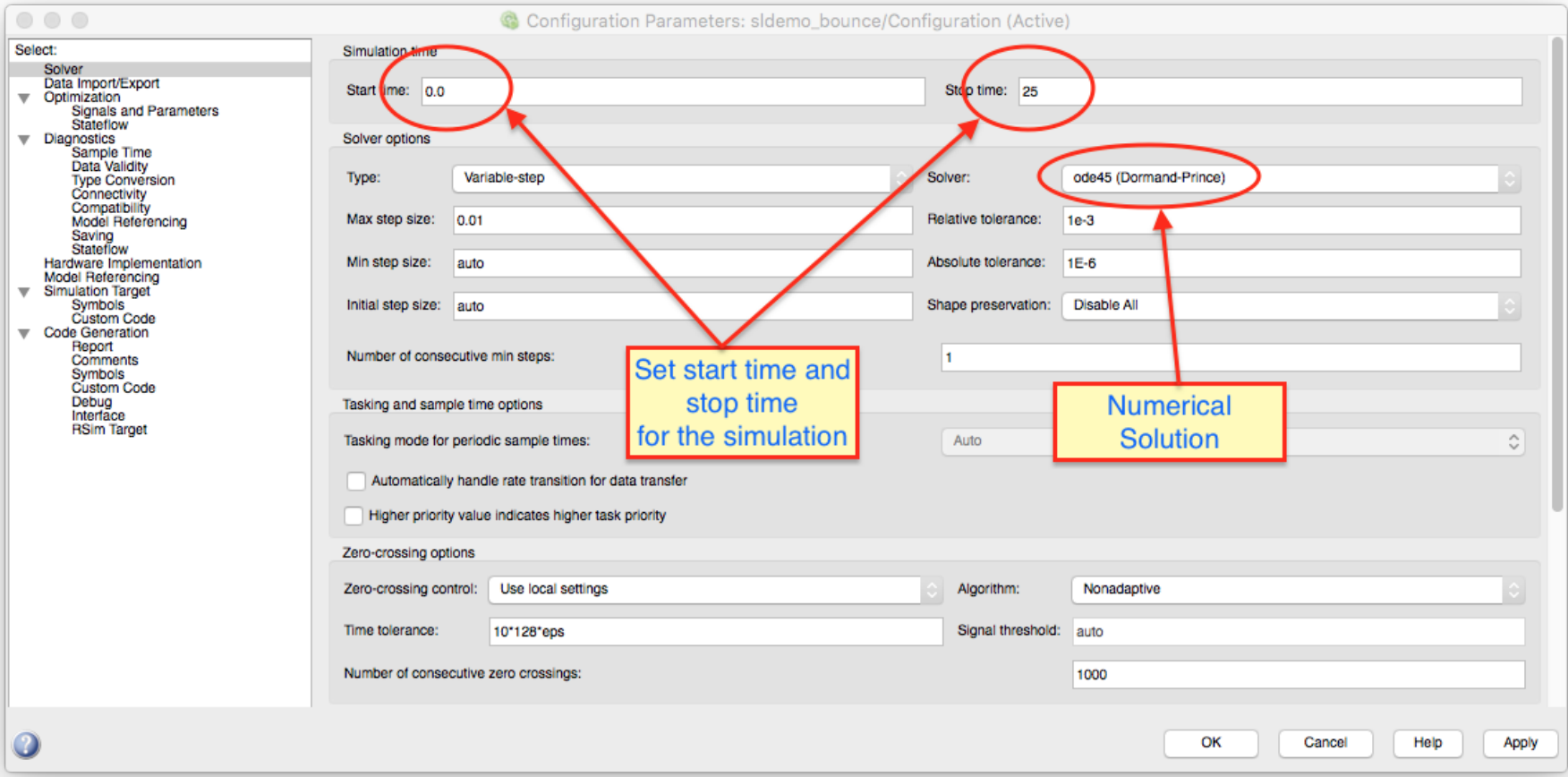
Variable step solver

The time step added to the current time can vary depending on the dynamics of the system. (i.e. ode45, ode23, ode113, ode15s, ode23s, ode23t, ode23tb)

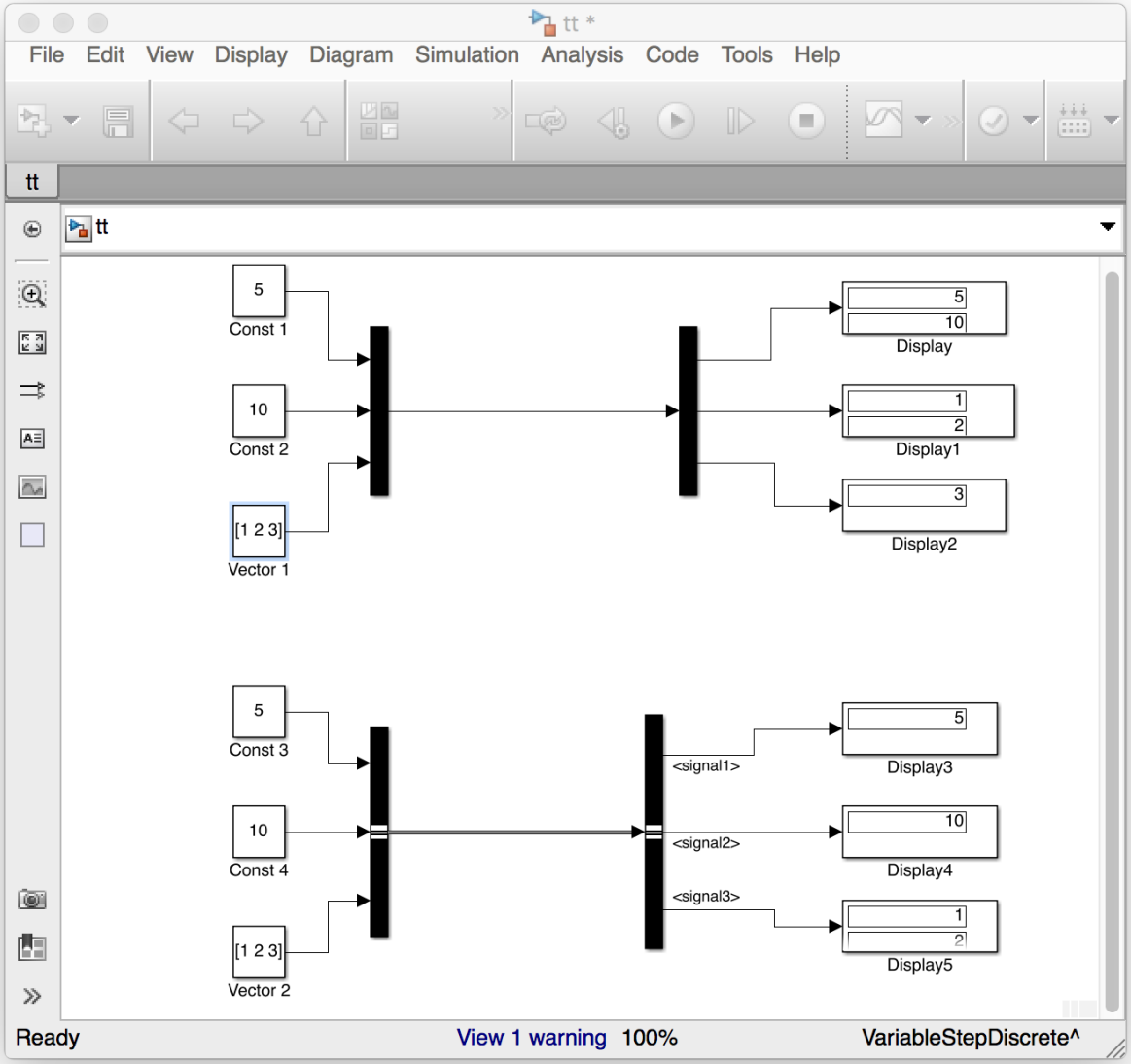
Fixed step solver

Step size remains constant. They do not control integration errors or detect discontinuities. (ode1, ode2, ode3, ode4, ode5, ode8)

Solver


Configuration Parameters: sldemo_bounce/Configuration (Active)
Select:
Solver
Data Import/Export
Optimization
Signals and Parameters
Stateflow
Diagnostics
Sample Time
Data Validity
Type Conversion
Connectivity
Compatibility
Model Referencing
Saving
Stateflow
Hardware Implementation
Model Referencing
Simulation Target
Symbols
Custom Code
Code Generation
Report
Comments
Symbols
Custom Code
Debug
Interface
RSim Target
Simulation time
Start time: 0.0
Stop time: 25
Solver options
Type: Variable-step
Solver: ode45 (Dormand-Prince)
Max step size: 0.01
Relative tolerance: 1e-3
Min step size: auto
Absolute tolerance: 1E-6
Initial step size: auto
Shape preservation: Disable All
Number of consecutive min steps: 1
Tasking and sample time options
Tasking mode for periodic sample times:
Auto
Automatically handle rate transition for data transfer
Higher priority value indicates higher task priority
Zero-crossing options
Zero-crossing control: Use local settings
Algorithm: Nonadaptive
Time tolerance: 10*128*eps
Signal threshold: auto
Number of consecutive zero crossings: 1000
OK
Cancel
Help
Apply
Set start time and stop time for the simulation
Numerical Solution

Mus, Demux and Bus



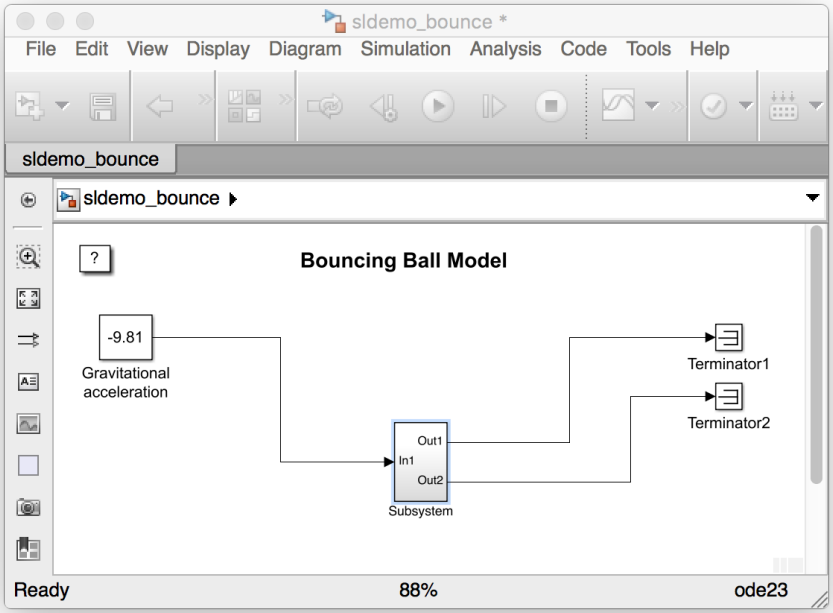
Subsystem

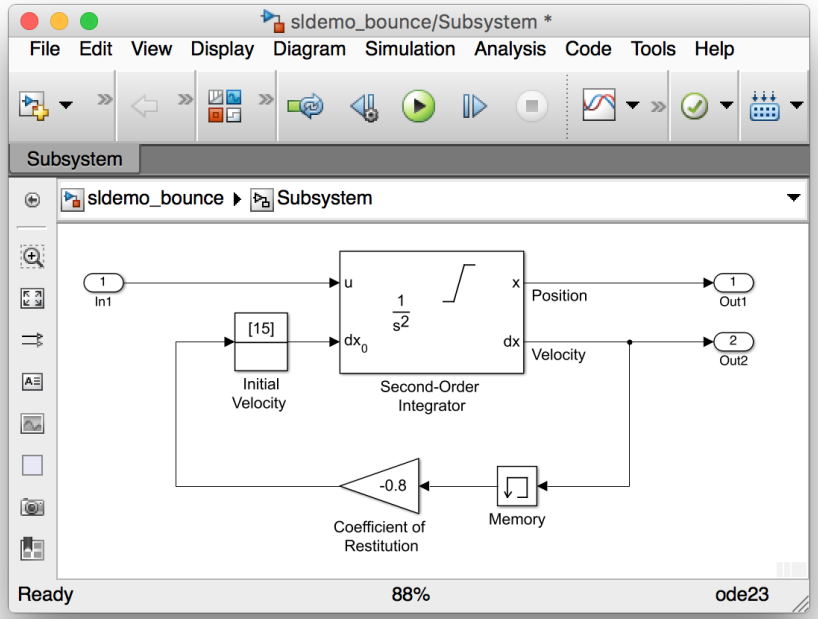
Subsystem

A subsystem block allows to contains a subset of blocks or code within a model to organise and to provide a hierarchical layout or to form a virtual subsystem. The prime benefits are given as follows:

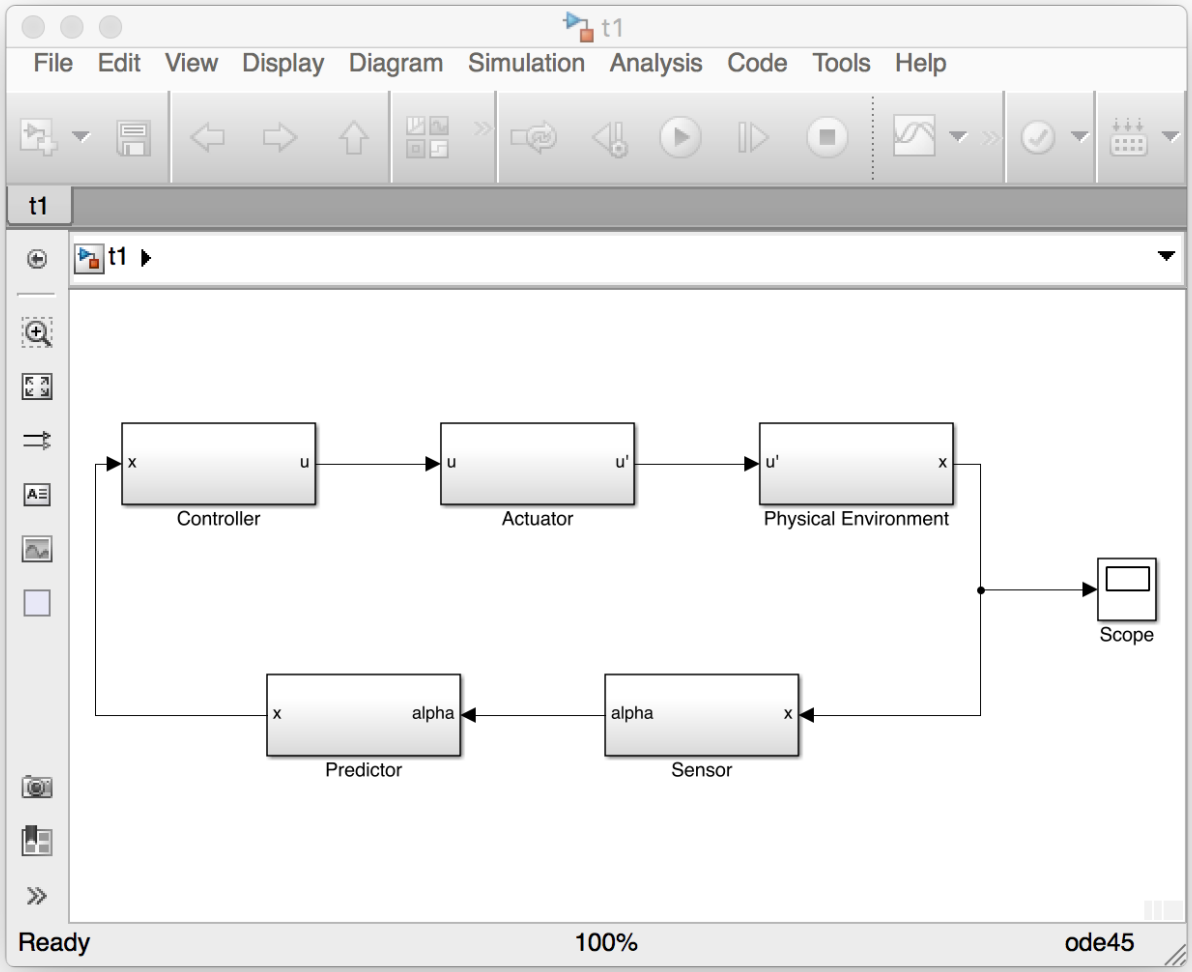
- To reduce a set of displayed blocks in a model window
- To keep functionally related block together to increase comprehensibility
- To provide a better layout in form of hierarchical block diagram

Subsystem: Example





Closed-loop Modelling



Stateflow

Stateflow

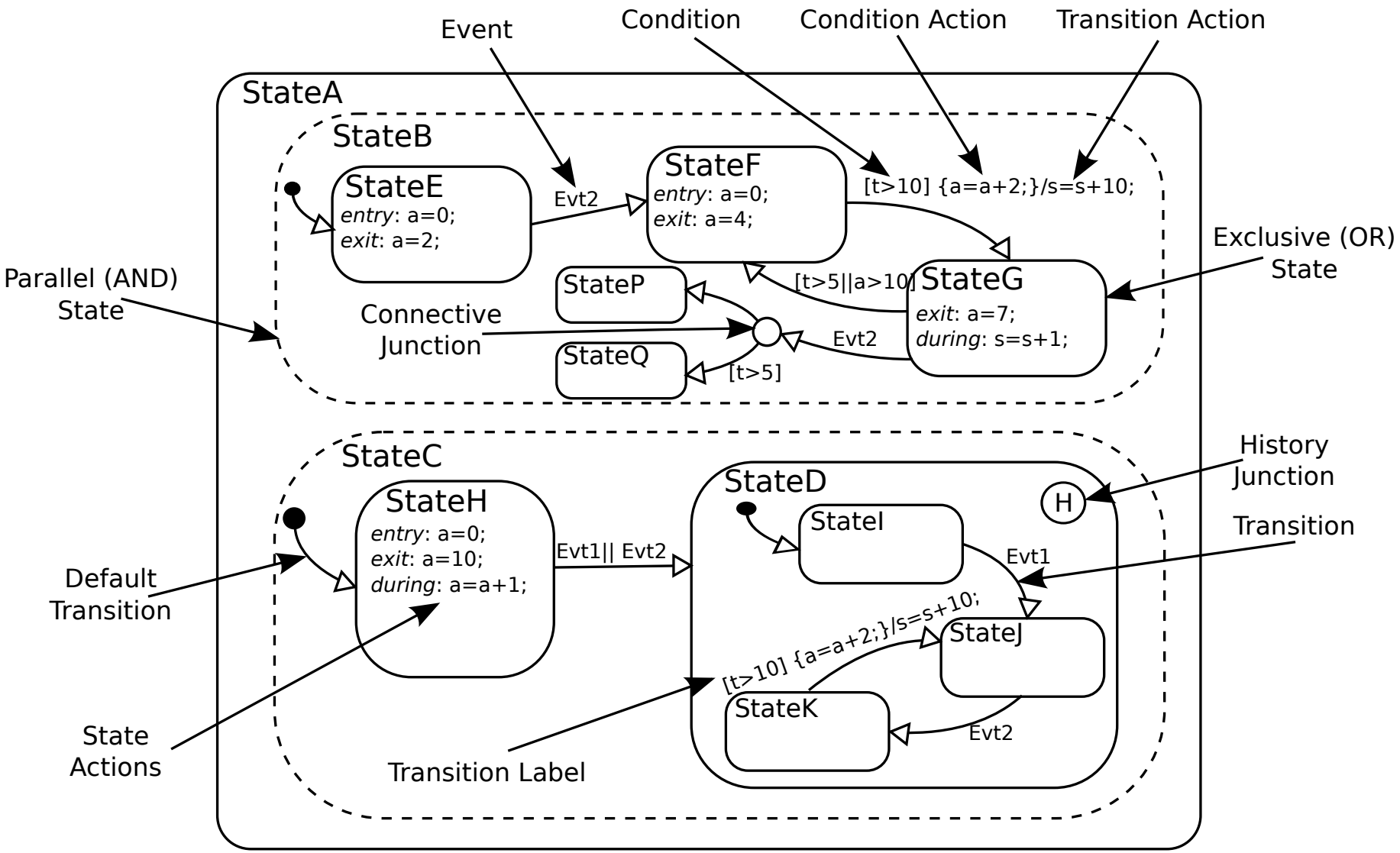
Stateflow is a graphical modelling language for specifying the behaviours of reactive systems using hierarchical state machines, similar to those of Statecharts (semantically different). It includes

- event broadcasting
- interlevel transition
- complex transition through junctions

Main Elements of Stateflow

- States
- Transitions
- Events
- Junctions

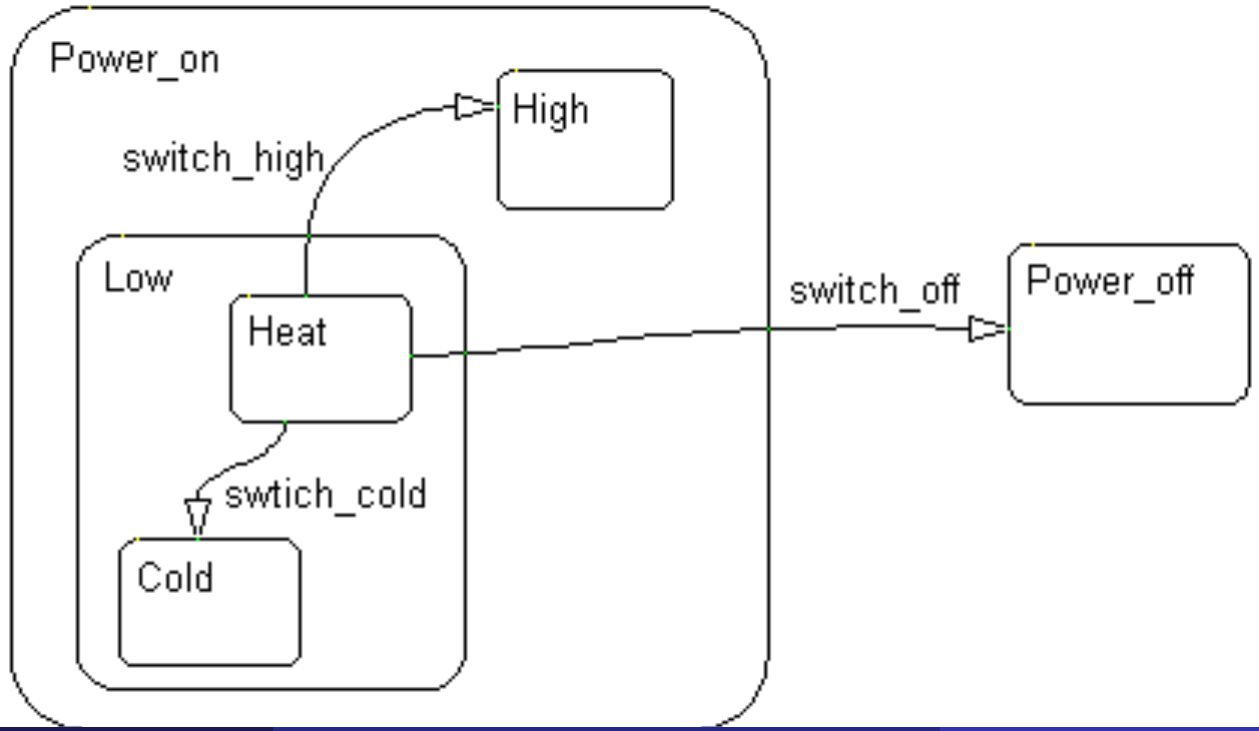
Stateflow Components



States

A state describes a mode of a reactive system. The activity or inactivity of the states dynamically changes based on events and conditions. States can be defined as:

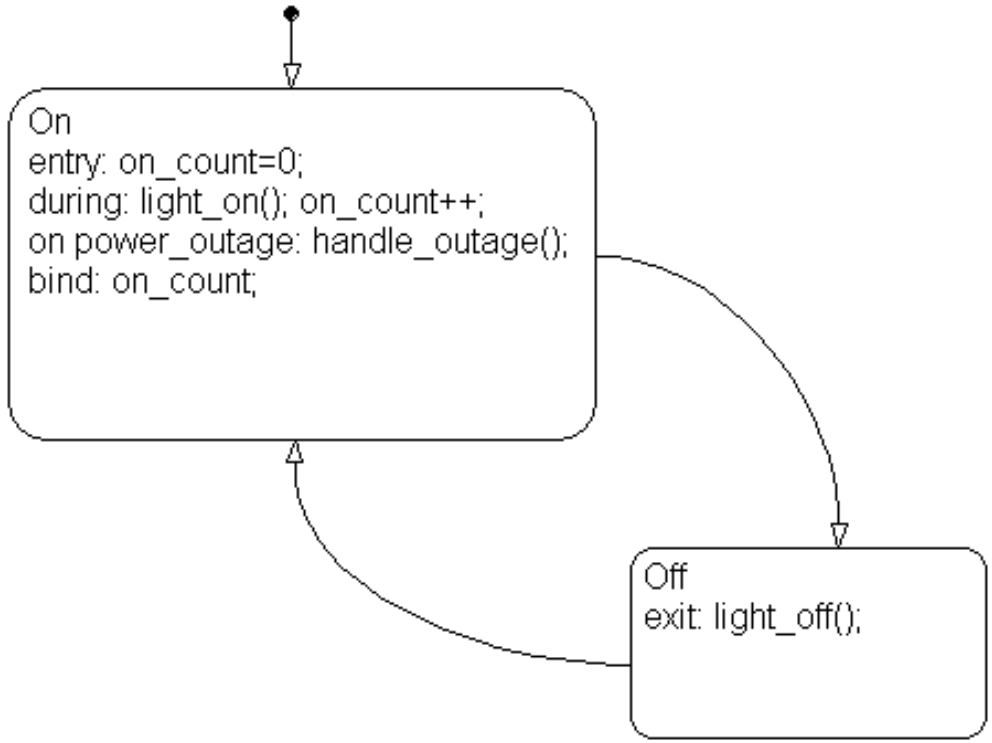
- Superstate
- Substate
- State



State Actions

States can have different types of actions, which can be executed in a sequence. For example,

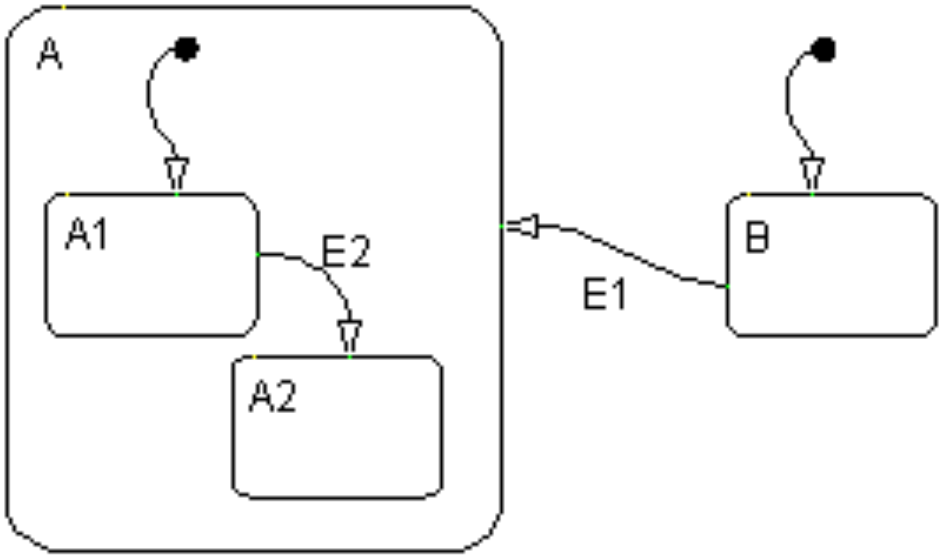
- *entry* actions, performed when entering a state
- *exit* actions, performed when leaving the state
- *during* actions, performed when remaining in the state
- etc.

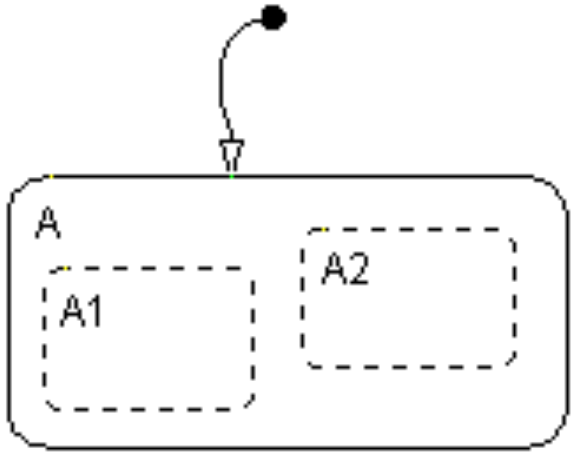


State Decomposition

The decomposition of a state defines the same compositional structure of substates. There two types of compositional structure.

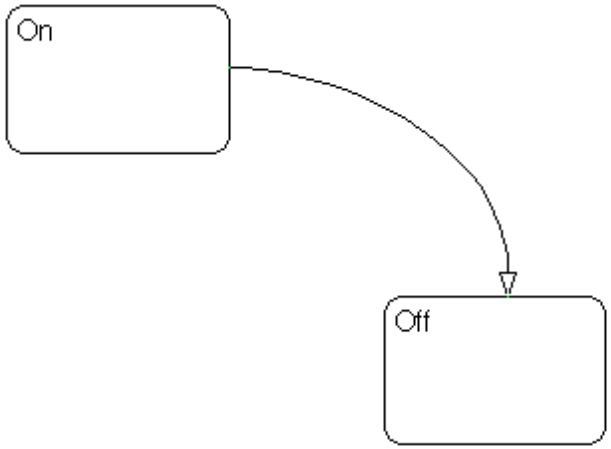
- Exclusive (OR)
- Parallel (AND)

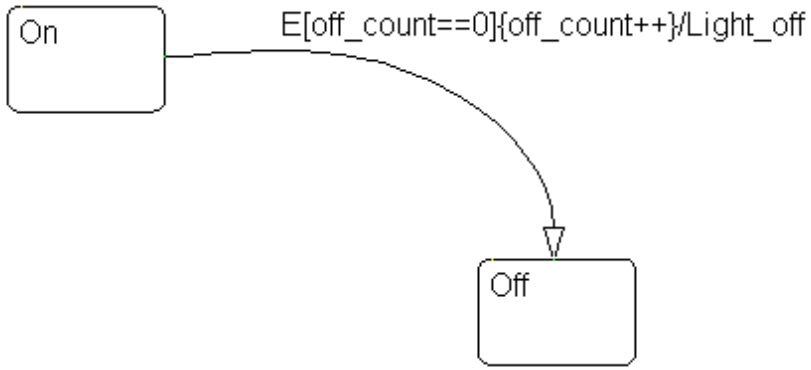




Transitions

A transition is a line or curve with an arrowhead that connects two states. The transition shows changing from one mode to other mode.





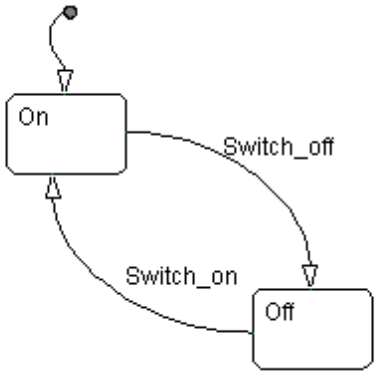
Transition Label Notation

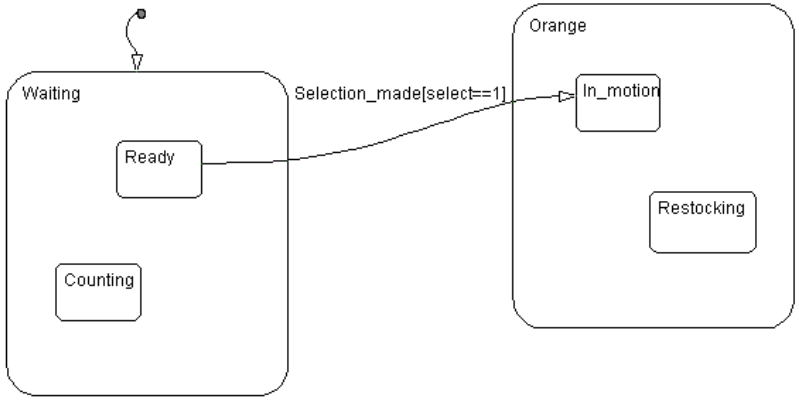
event [condition] {condition_action} / transition_action

Transition Connections

Transition

Default transitions are used to distinguish as a default enter state to avoid the ambiguity among two or more exclusive (OR)-states.





There are several other transitions. For example,

- Transition to and from OR States
- Transition to and from Junctions
- Transition to and from OR Superstates
- Transition to and from OR Substates
- Self-Loop Transitions, etc.

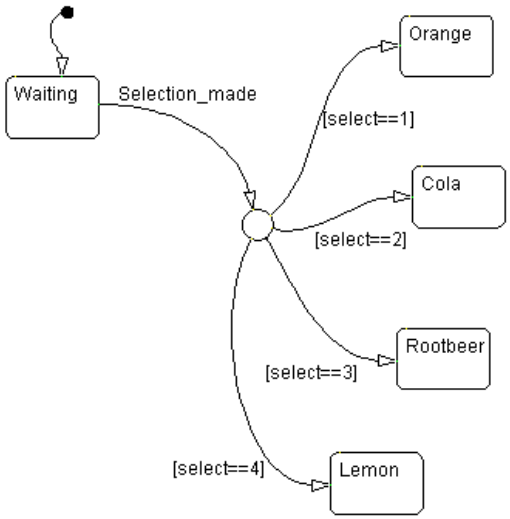
Junctions

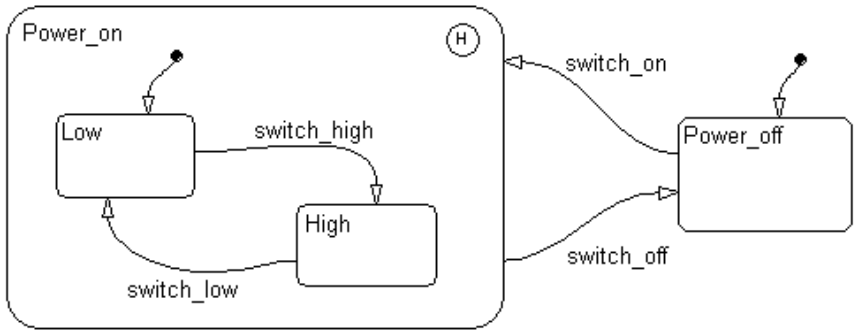
Connective Junctions

The connective junction enables representation of different possible transition paths for a single transition. It is mainly used for implementing *if − then − else*, *case*, *for loop*, etc.

History Junctions

History junctions record the previously active state of the state in which they are resident.





Events

Events handle the execution of the Stateflow diagram without using any graphical components. The broadcast of an event must trigger a transition or an action during execution. Events are broadcasted in top-down manner. The scope of events can be,

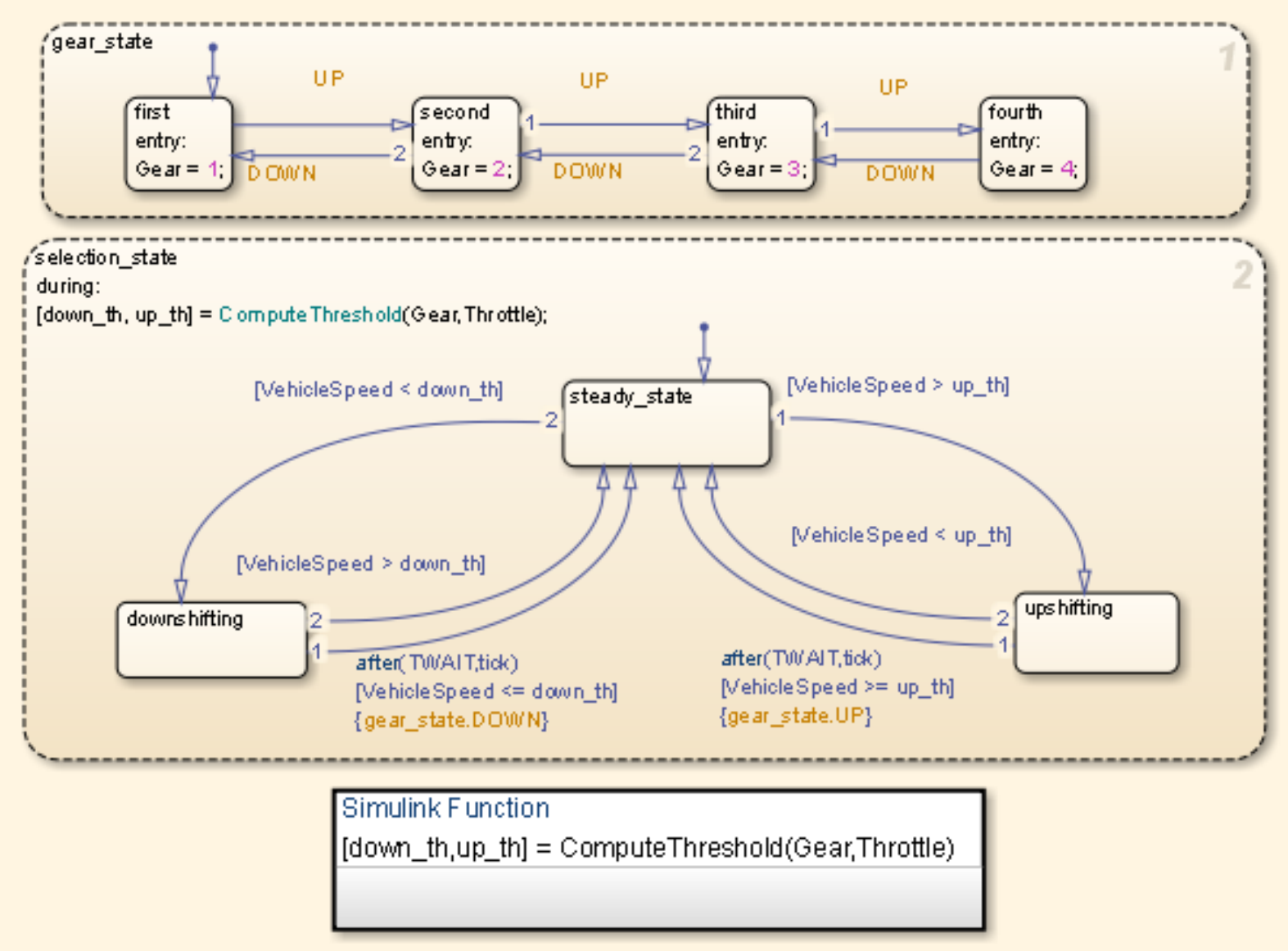
- local
- input from the Simulink
- output to the Simulink
- exported to code block or Simulink model
- imported from code block or Simulink model

Stateflow Simulation Algorithm

Starts each time an input event arrives (external or internal event), recursively.

- search for active states
- search for valid transitions
- valid transition execution
- during action execution

Example


gear_state
1
UP
UP
UP
first
entry:
Gear = 1;
second
entry:
Gear = 2;
third
entry:
Gear = 3;
fourth
entry:
Gear = 4;
DOWN
DOWN
DOWN
selection_state
2
during:
[down_th, up_th] = ComputeThreshold(Gear,Throttle);
steady_state
[VehicleSpeed < down_th]
[VehicleSpeed > up_th]
[VehicleSpeed > down_th]
[VehicleSpeed < up_th]
downshifting
upshifting
after(TWAIT,tick)
[VehicleSpeed <= down_th]
{gear_state.DOWN}
after(TWAIT,tick)
[VehicleSpeed >= up_th]
{gear_state.UP}
Simulink Function
[down_th,up_th] = ComputeThreshold(Gear,Throttle)

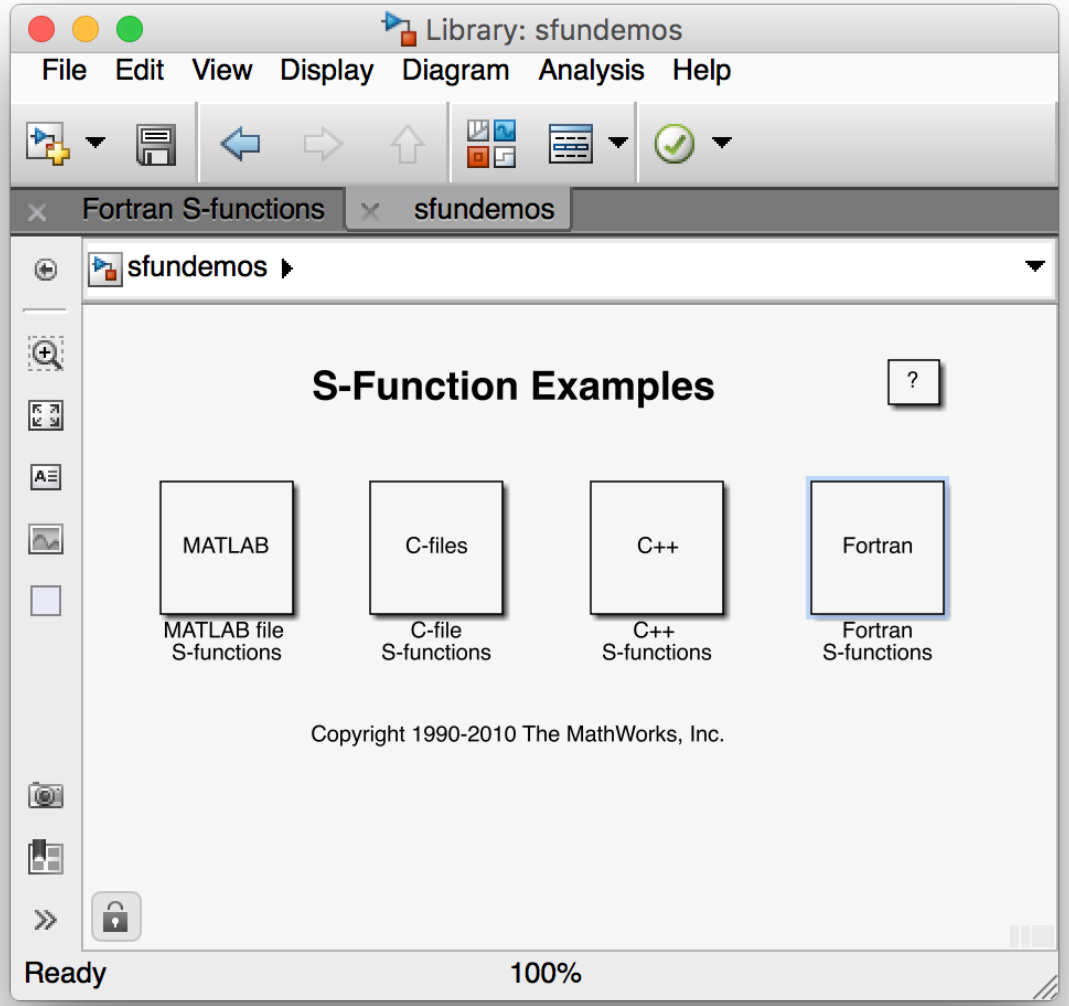
S-Function

S-Function

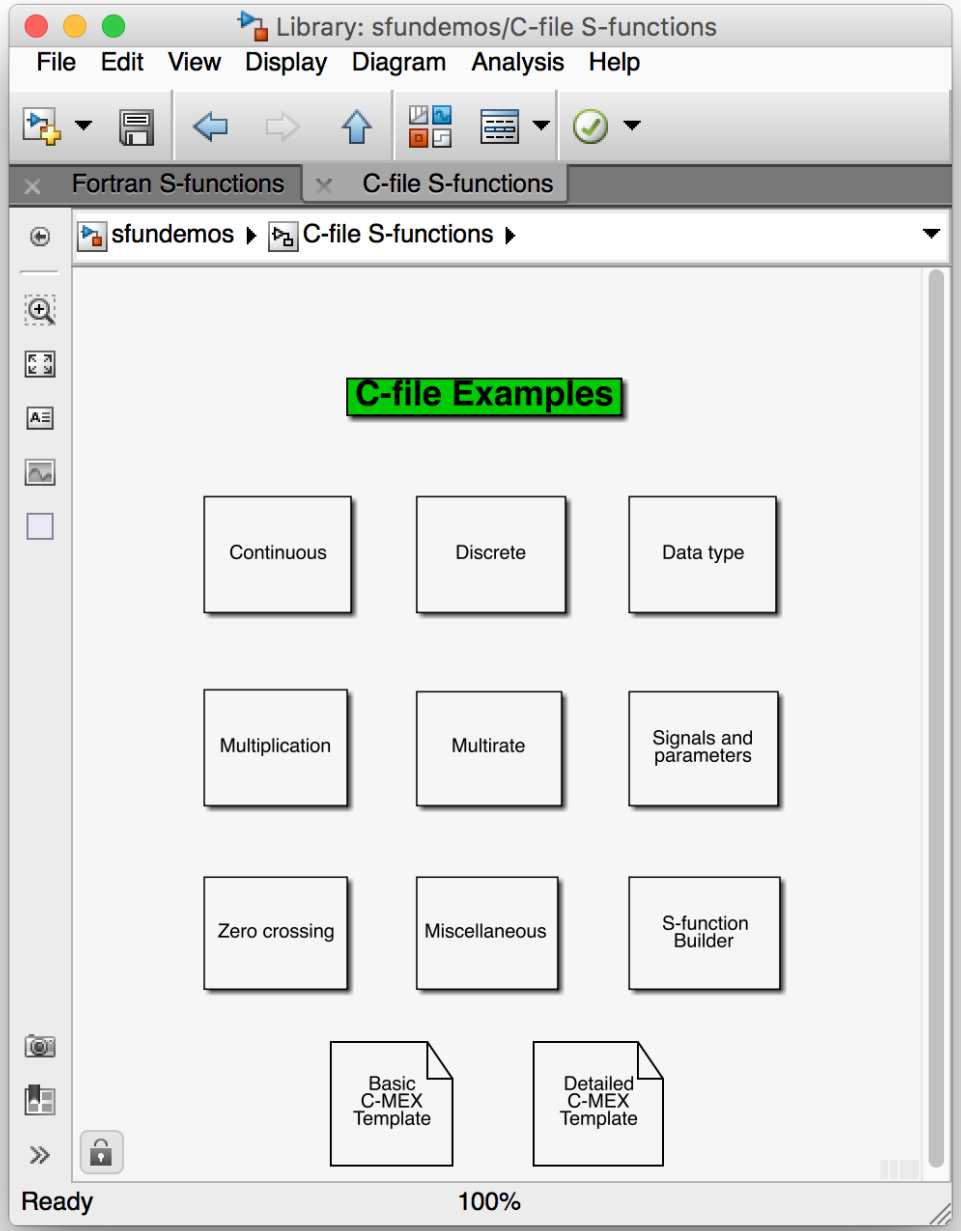
S-Function is a programming language environment in form of Simulink blocks that allows to add your own code to Simulink model. The S-Function block supports the following programming languages:

- MATLAB (M-file S-Function)
- C (C Mex S-Function)
- C++ (C Mex S-Function)
- Fortran (C Mex S-Function)

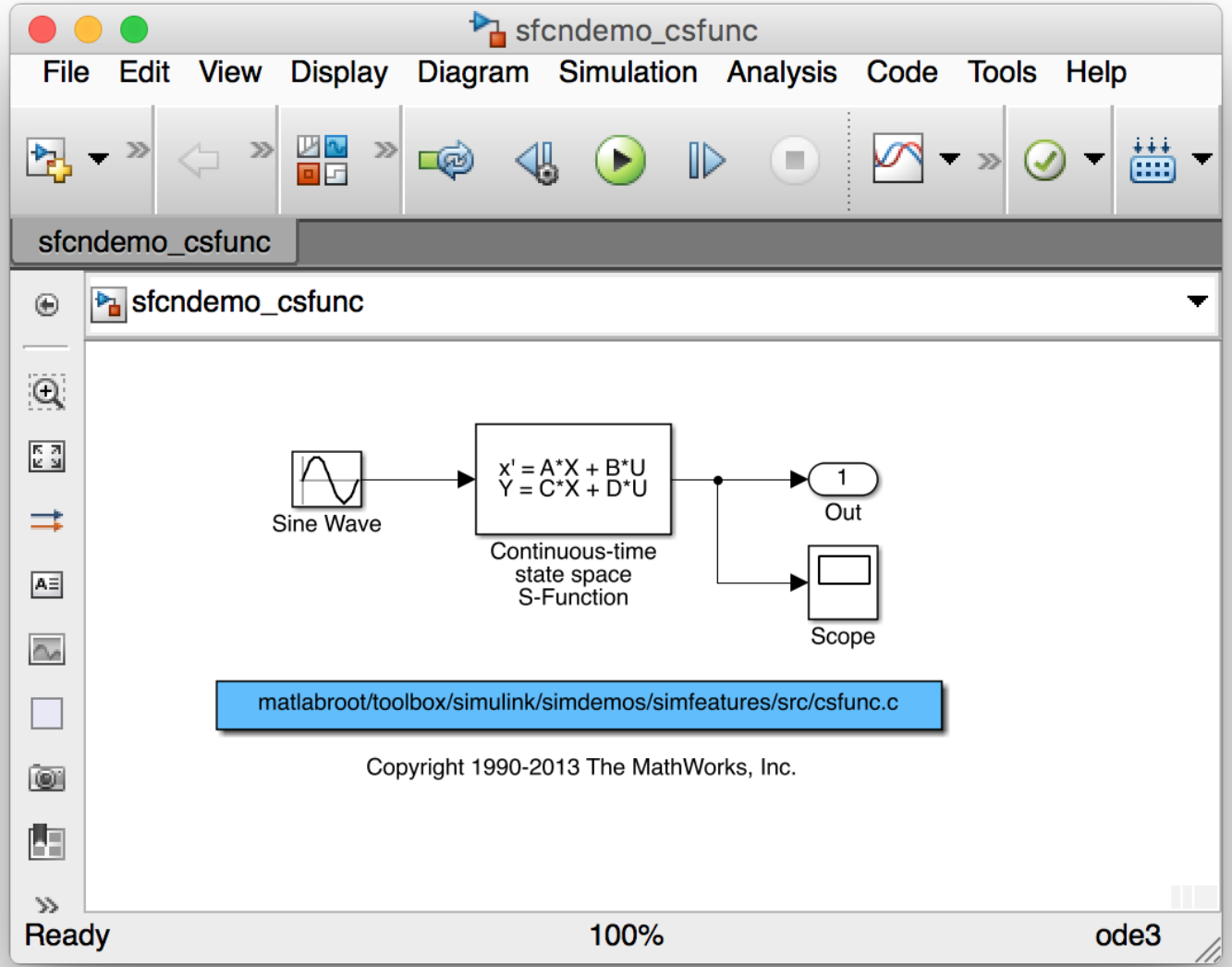
S-Function Examples



S-Function Examples in C Language



S-Function: Continuous Time System



S-Function Templates

1. C Language Template
2. MATLAB Language Template
3. ...