

# How to Build a Simple Stateflow Model

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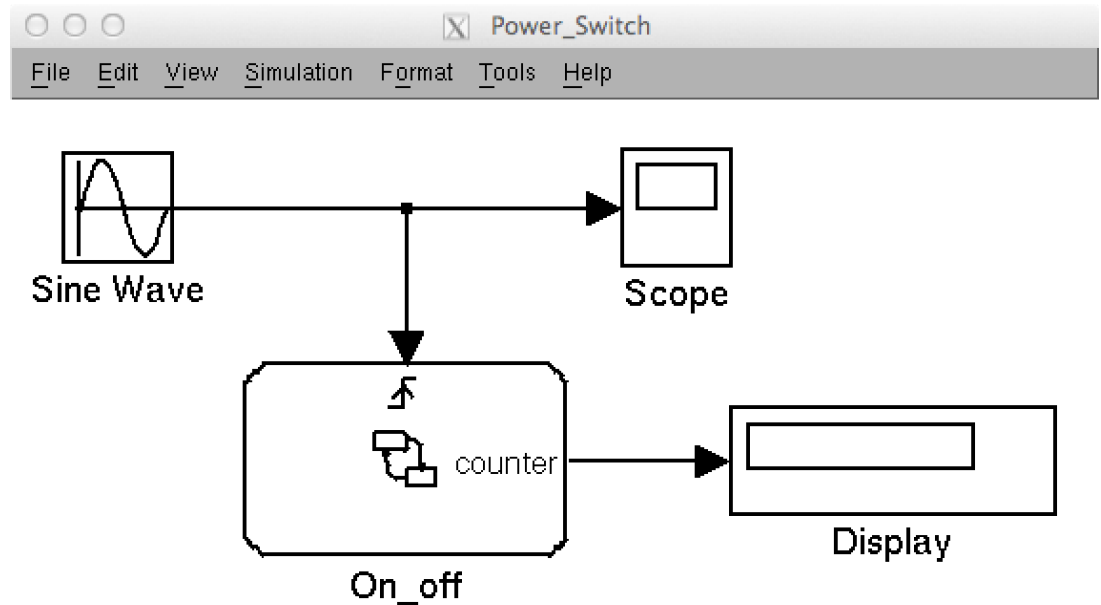
EECS 461: Embedded Control Systems

# Introduction

- This set of slides will show you how build a simple model using Simulink and Stateflow.
- We will use 32-bit Matlab release 2011b, the same version of Matlab as currently used in the EECS 461 Embedded Control Lab.
- Instructions for installing 32-bit Matlab 2011b on your laptop are contained in the “Course Logistics” document on CTools
- Recently Matlab has changed from models with a .mdl suffix to models with a .slx suffix. (The underlying software is different, and enables additional features.)
- If you insist on using a more recent version of Matlab, and you want me to examine your model for debugging, then you should save your model as a .mdl file In Matlab 2011b. Look for a “save as” command, or perhaps an “export” command. (Different versions of Matlab do this differently.)

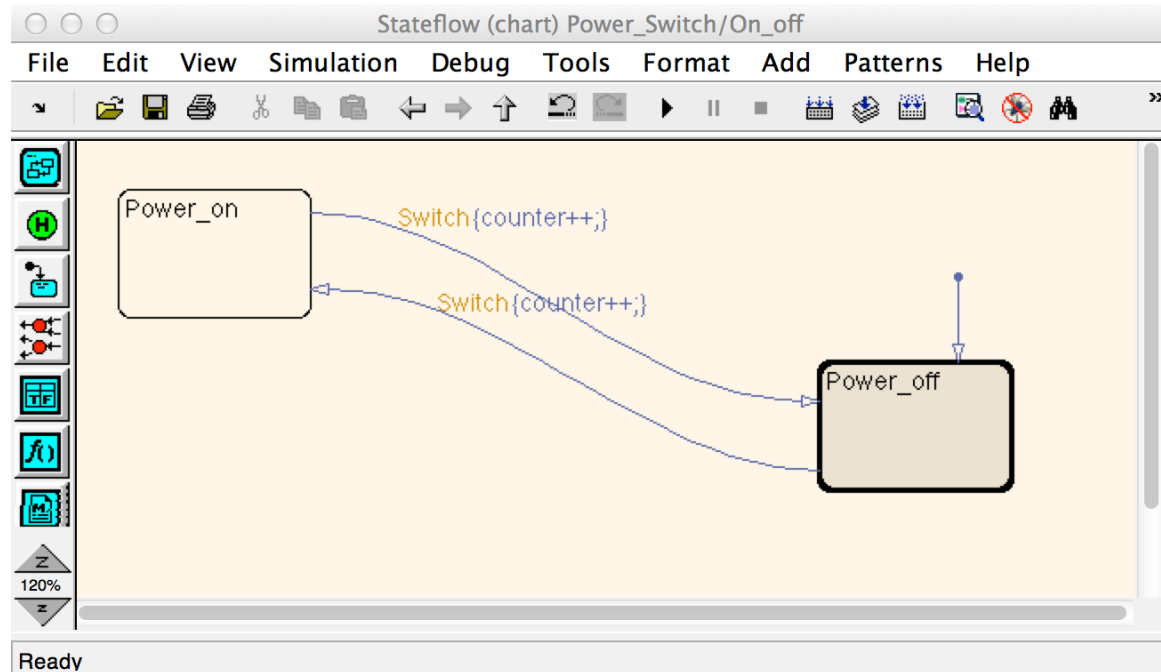
# Power Switch Simulink Model

- Simulink model of a power switch that toggles on and off at zero crossing of a sine input.
- At each switch, a counter is incremented



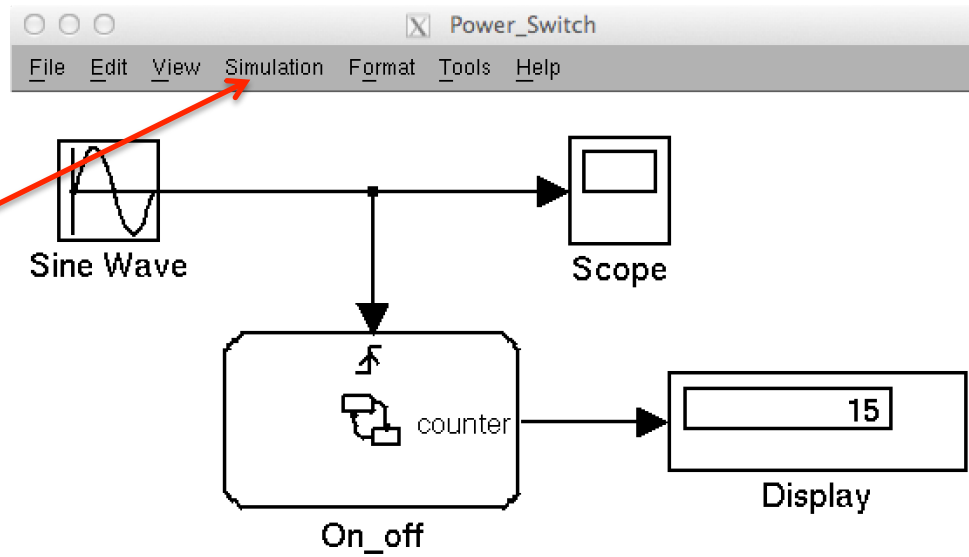
# Inside the State Chart

- Two states of the power switch: on and off
- Transitions between the States happen whenever the event “switch” occurs.
- When a transition occurs, the variable “counter” is incremented
- By default, the initial state is “off”

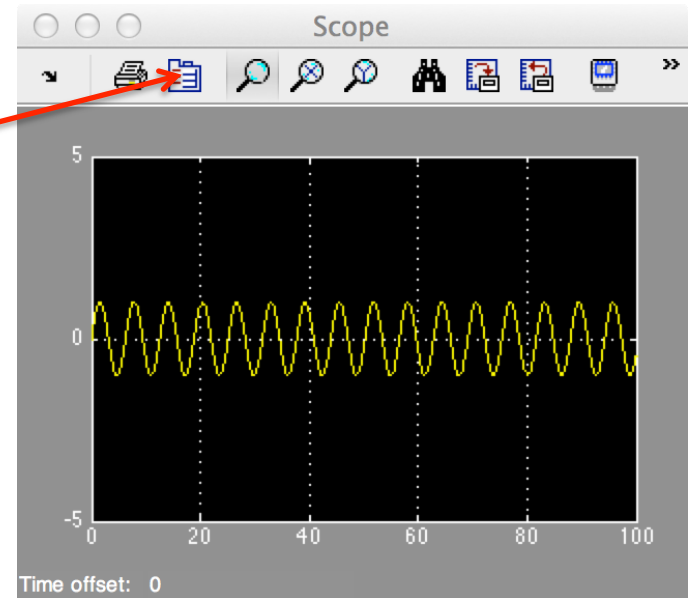


# To Run Simulation

- Open Scope by clicking on it
- Run simulation by selecting “start” from the Simulation menu

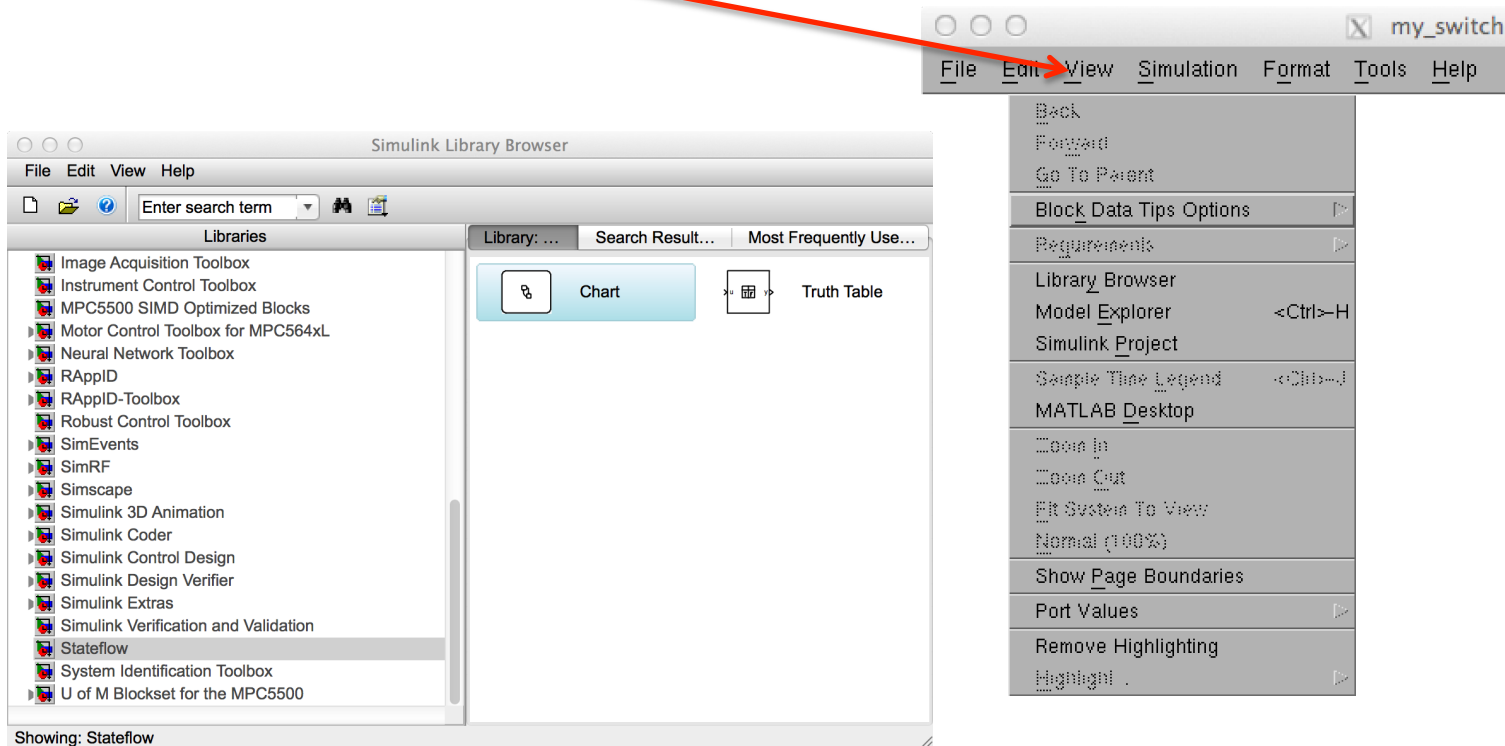


- If the Scope does not display the entire sine waveform, go to the Scope parameters menu, navigate to the History submenu, and turn off the “Limit data points” option.
- Change the size or colors of the plotted lines using the Graphics submenu



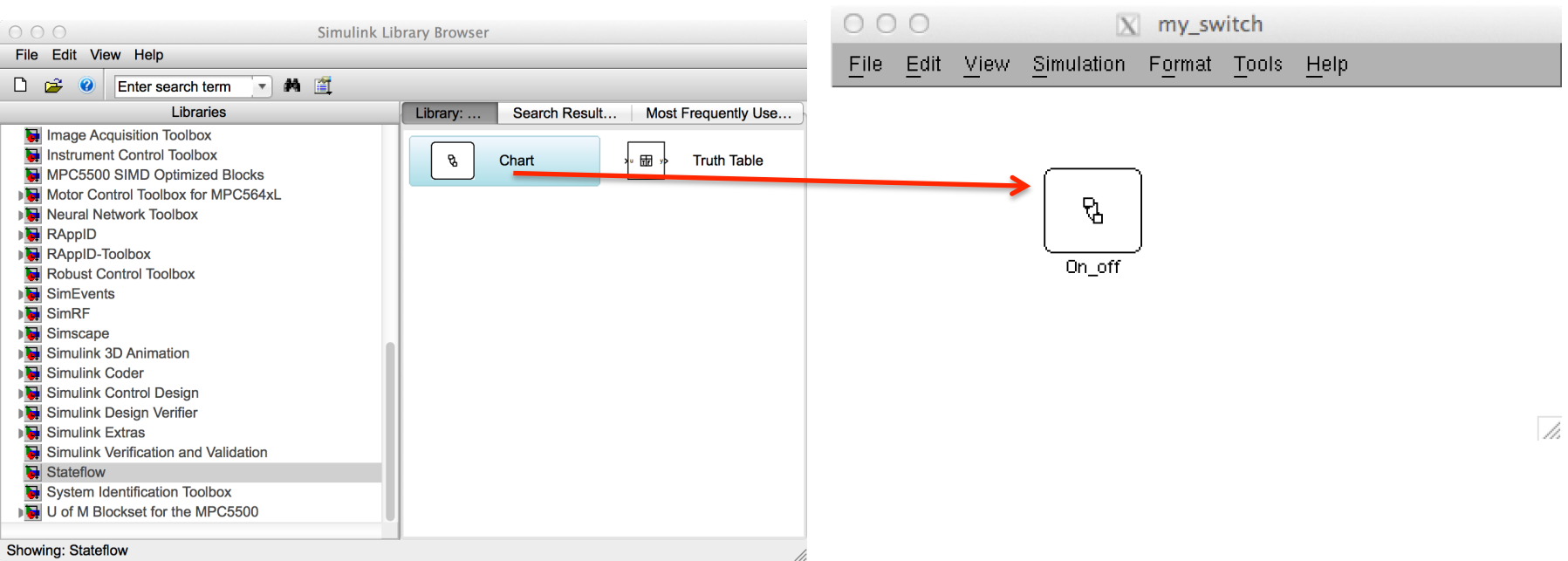
# Create Simulink Model

- Create a new Simulink model by selecting File/New/Model in the Matlab command window.
- Save the model with a name, e.g. “my\_switch”
- In the View Menu, select “Library Browser” and navigate down to Stateflow



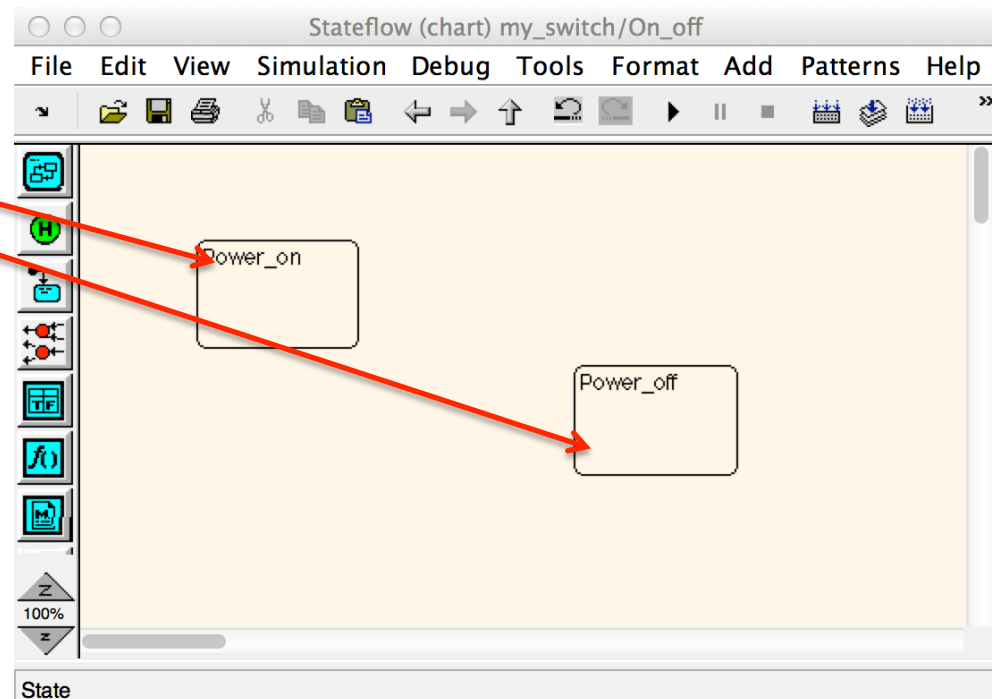
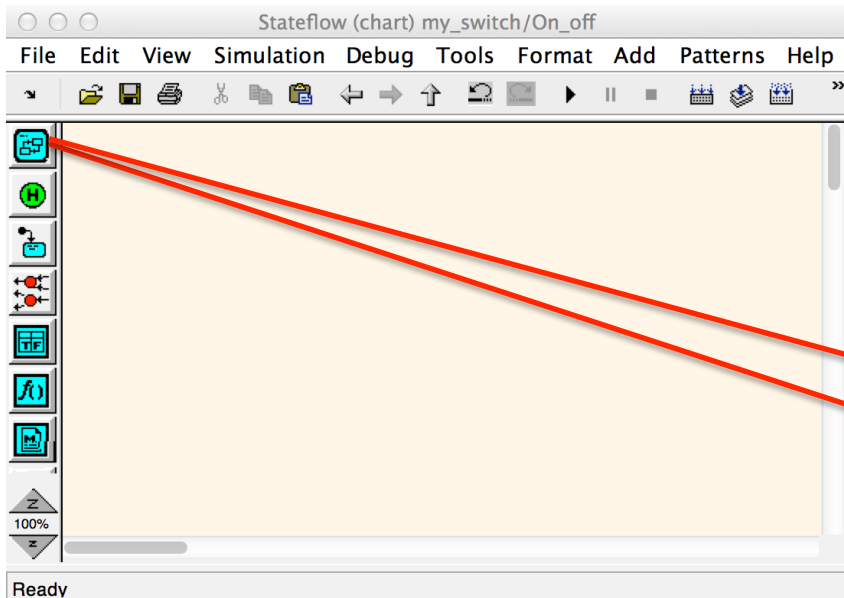
# Add Statechart to Simulink Model

- Drag Statechart to the Simulink model
- Change name from “Chart” to “On\_off”



# Adding States to a Statechart

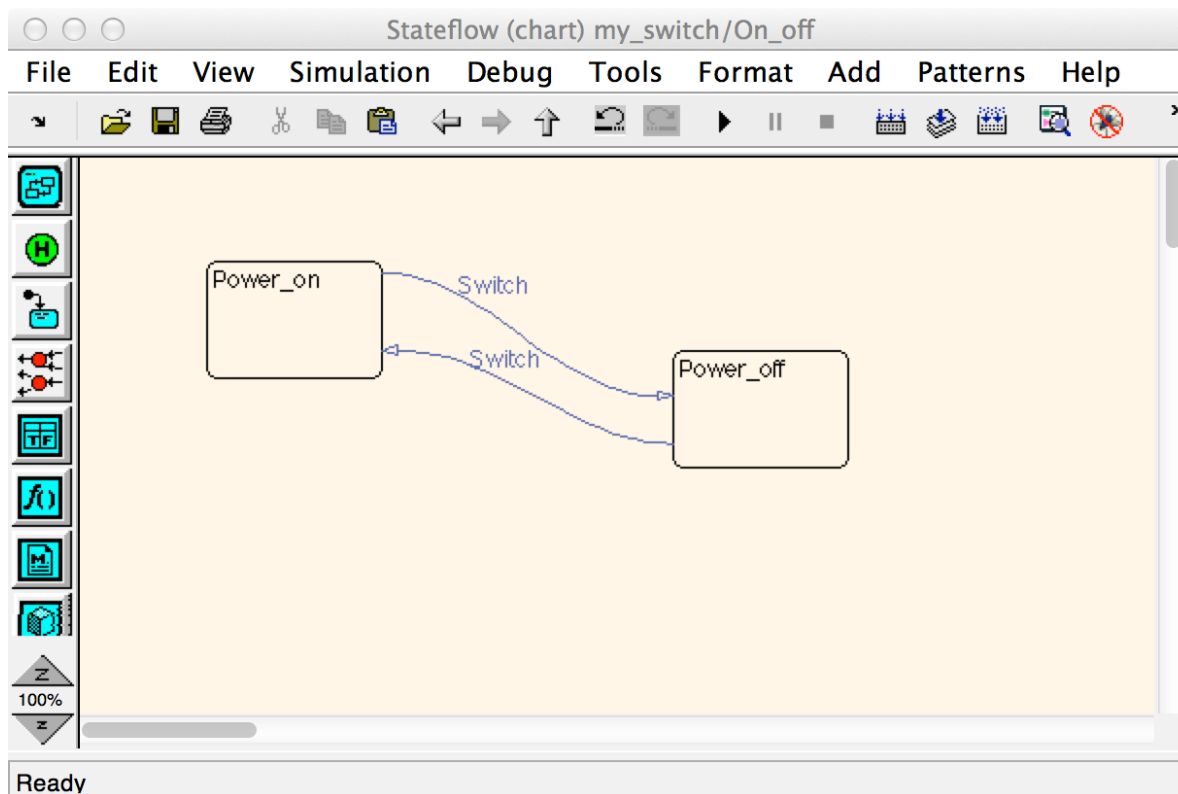
- Open Statechart “On\_off” by double-clicking
- Drag two states from the menu at left into the chart.
- Name them “Power\_on” and “Power\_off” by editing the ? In the upper left corner
- NOTE: to delete a state, highlight it and select “Cut” from the “Edit” menu





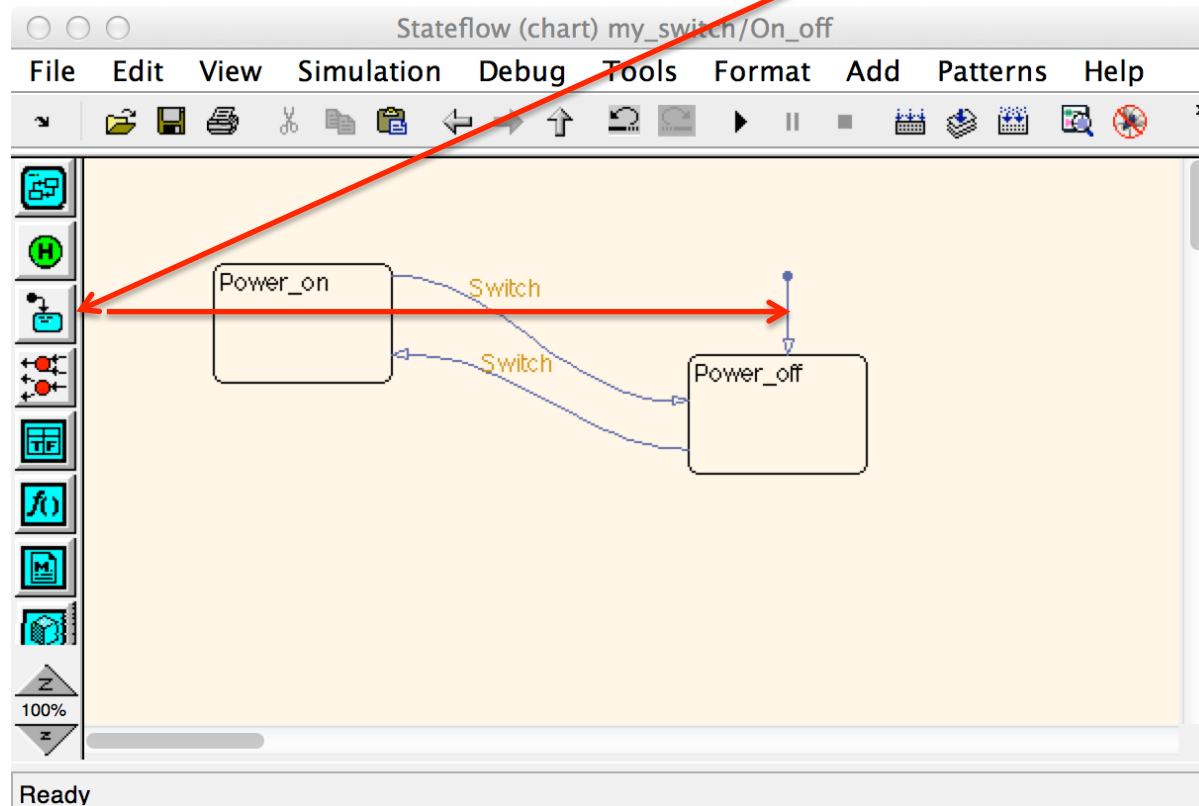
# Creating Transitions between States

- To create a transition between states, hold the cursor over the border of the starting state – it will turn into crosshairs.
- Hold down the mouse button drag the mouse to the terminal state – this will create a transition (denoted by an arrow) connecting the states
- Click on the transition and replace the resulting ? with the name of the event that causes the transition.



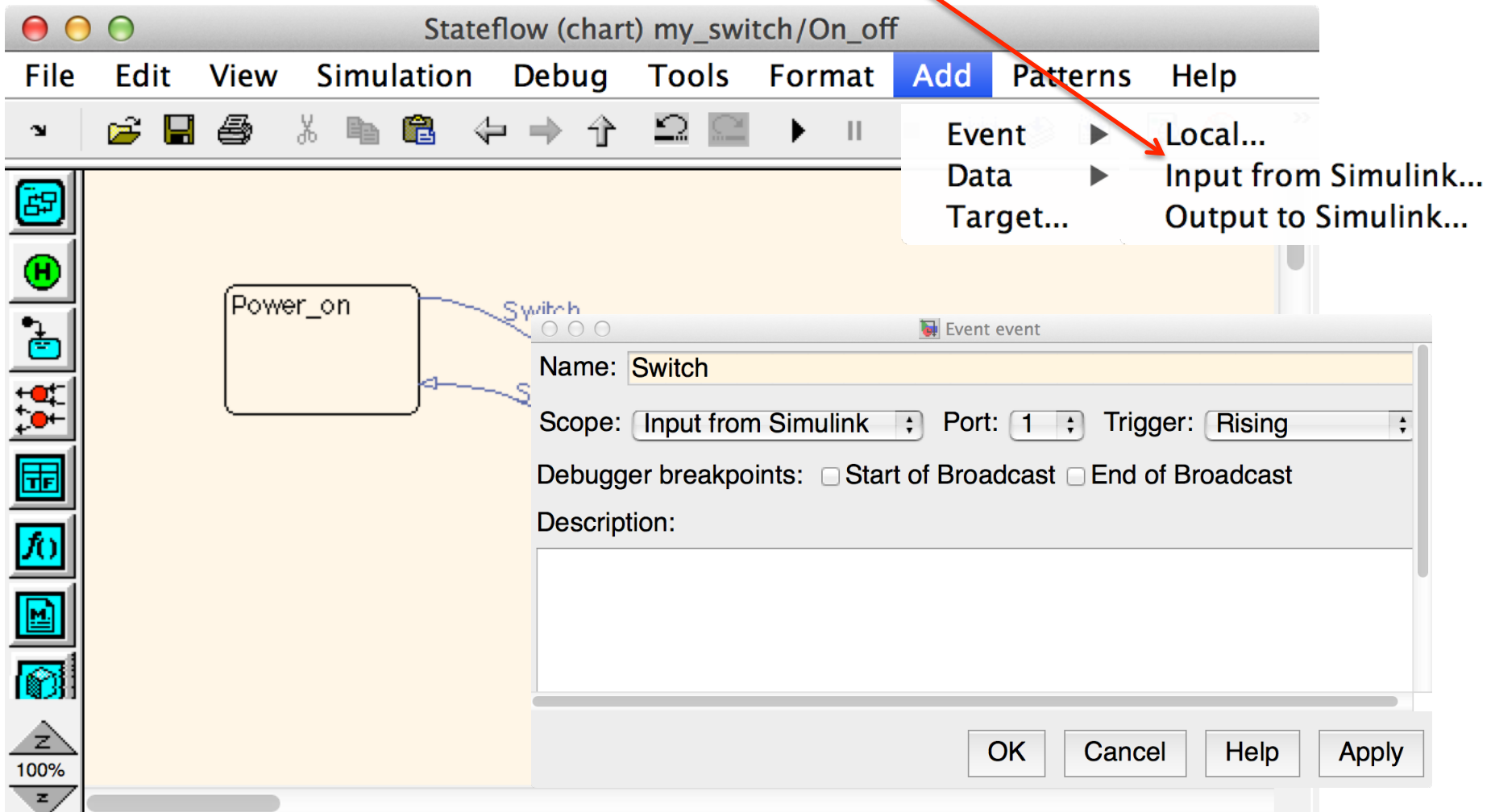
# Add a Default Transition

- Specify the initial state (Power\_off in this case) by adding a default transition



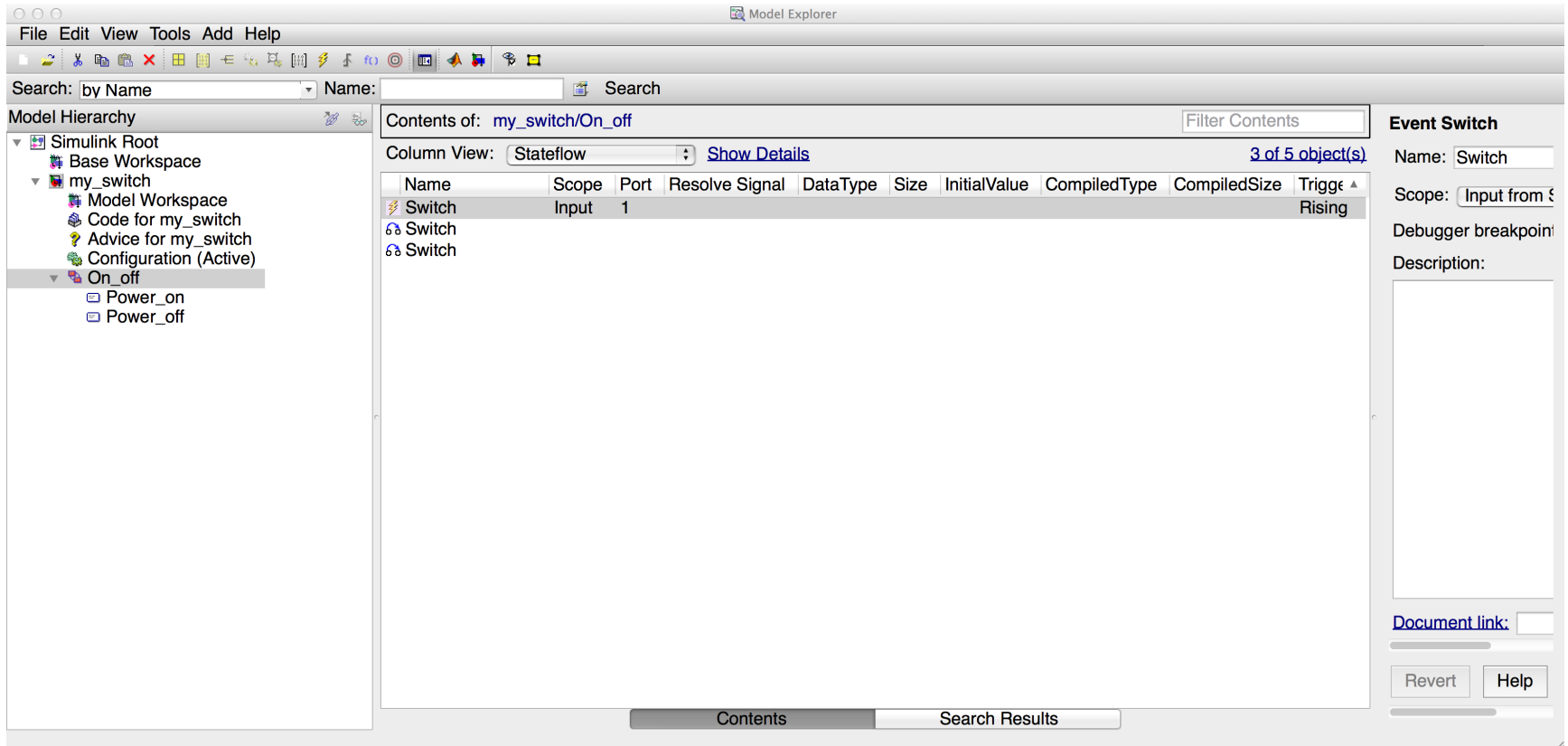
# Adding an Event

- Add an event that is “Input from Simulink”
- A window will open allowing you to name the event (call it Switch), and to specify what triggers the event. In our case, use rising edges of a sine wave.
- If you add multiple events input from Simulink, the Port menu will have more than option.



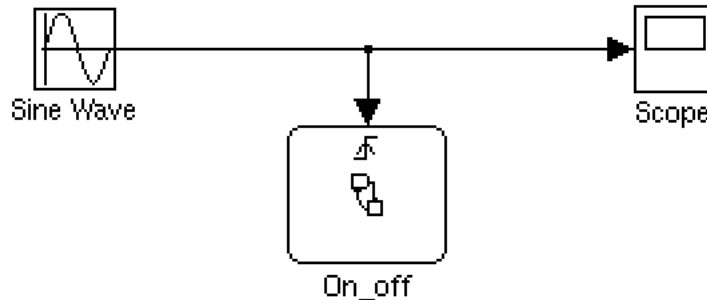
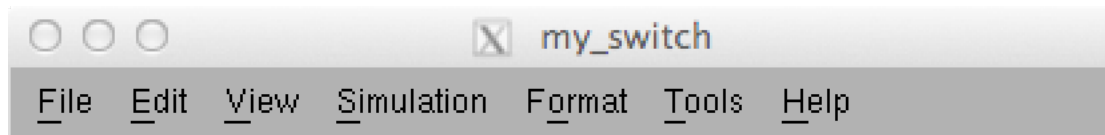
# The Model Explorer

- Open the Model Explorer by selecting the Tools/Explore option from the Statechart menu
- This menu allows you to edit the event you have just defined, and to add new events
- On a small screen, you may need to scroll the menu left and right to see the “Trigger” option



# Adding the Sine Input

- Return to the top-level Simulink diagram
- The Statechart “On-off” now has an arrow entering it.
- Add a Sine Wave input from the View/Library Browser/Sources menu
- Add a Scope from the View/Library Browser/Sinks menu
- Use the mouse to connect these blocks.
- Double click on the Sine Wave block and specify the parameters as shown.



Source Block Parameters: Sine Wave

Output a sine wave:

$$O(t) = \text{Amp} \cdot \sin(\text{Freq} \cdot t + \text{Phase}) + \text{Bias}$$

Sine type determines the computational technique used. The parameters in the two types are related through:

$$\text{Samples per period} = 2\pi / (\text{Frequency} \cdot \text{Sample time})$$
$$\text{Number of offset samples} = \text{Phase} \cdot \text{Samples per period} / (2\pi)$$

Use the sample-based sine type if numerical problems due to running for large times (e.g. overflow in absolute time) occur.

Parameters

Sine type:

Time (t):

Amplitude:

Bias:

Frequency (rad/sec):

Phase (rad):

Sample time:

☒ Interpret vector parameters as 1-D

OK Cancel Help Apply

# Configuration Parameters

- From the Simulink model “my\_switch”, select Simulation/Configuration Parameters/Solver
- Specify Start time = 0; Stop time = 100; Fixed Step Solver with Step size 0.001;
- Use a discrete solver since we only have states that take discrete values (on or off)
- Apply the changes and close the window.

The screenshot shows the 'Configuration Parameters: my\_switch/Configuration (Active)' dialog box. On the left is a 'Select:' sidebar with a tree view containing: Solver, Data Import/E..., Optimization, Diagnostics, Hardware Imp..., Model Refere..., Simulation Tar..., and Code Generat... The main area is divided into sections: 'Simulation time' with 'Start time: 0.0' and 'Stop time: 100.0'; 'Solver options' with 'Type: Fixed-step', 'Solver: discrete (no continuous states)', and 'Fixed-step size (fundamental sample time): .001'; and 'Tasking and sample time options' with 'Periodic sample time constraint: Unconstrained', 'Tasking mode for periodic sample times: Auto', and two unchecked checkboxes: 'Automatically handle rate transition for data transfer' and 'Higher priority value indicates higher task priority'. At the bottom are buttons for '?', 'OK', 'Cancel', 'Help', and 'Apply'.

Configuration Parameters: my\_switch/Configuration (Active)

Select:

- Solver
- Data Import/E...
- Optimization
- Diagnostics
- Hardware Imp...
- Model Refere...
- Simulation Tar...
- Code Generat...

Simulation time

Start time: 0.0 Stop time: 100.0

Solver options

Type: Fixed-step Solver: discrete (no continuous states)

Fixed-step size (fundamental sample time): .001

Tasking and sample time options

Periodic sample time constraint: Unconstrained

Tasking mode for periodic sample times: Auto

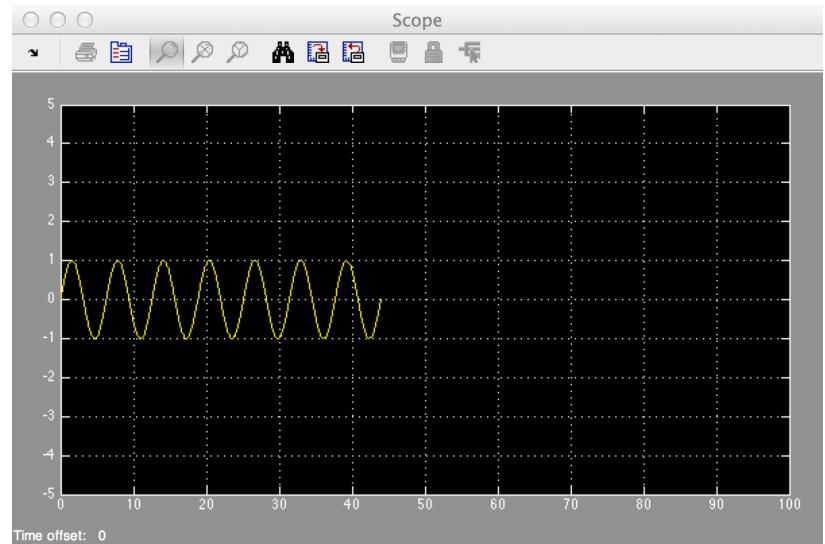
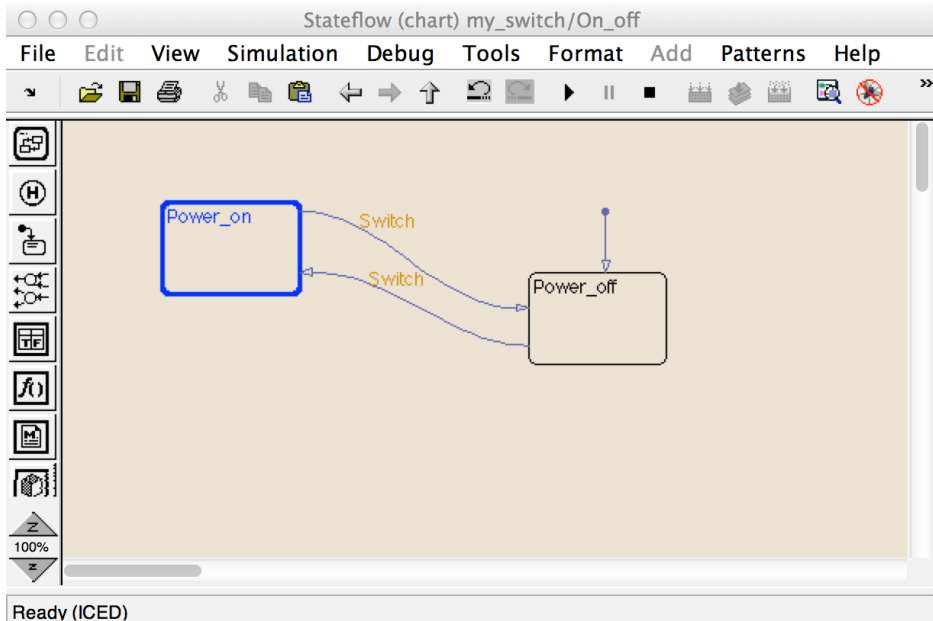
☐ Automatically handle rate transition for data transfer

☐ Higher priority value indicates higher task priority

OK Cancel Help Apply

# Running the Simulation

- Execute the simulation by selecting Simulation/Start
- The state changes from “Power\_on” to “Power\_off” at each rising zero crossing of the sine wave.



# Counting Transitions

- Add data that is “Output to Simulink”
- A window will open allowing you to name the data (call it “counter”), and to specify its data type: leave it set to the default “double”.
- Leave “initial value” blank to use the default value of zero

The screenshot shows the Stateflow (chart) my\_switch/On\_off window. The 'Add' menu is open, showing options: Event, Data, Target..., Local..., Input from Simulink..., Output to Simulink..., Constant..., Parameter..., and Data Store Memory... A red arrow points from the 'Add' button in the menu bar to the 'Output to Simulink...' option. The 'Data counter' dialog box is open, showing the 'General' tab. The 'Name' field is 'counter', 'Scope' is 'Output', 'Port' is '1', 'Type' is 'double', and 'Initial value' is 'Expression'. The 'Limit range' section has 'Minimum' and 'Maximum' fields. The 'Watch in debugger' checkbox is unchecked. The background shows a Stateflow chart with a 'Power\_on' block and two 'Switch' blocks.

Stateflow (chart) my\_switch/On\_off

File Edit View Simulation Debug Tools Format **Add** Pattern Local... Input from Simulink... Output to Simulink... Constant... Parameter... Data Store Memory...

Event Data Target...

**Data counter**

General Description

Name: counter

Scope: Output Port: 1

☐ Data must resolve to Simulink signal object

Size: Variable size

Complexity: Off

Type: double >>

☐ Lock data type setting against changes by the fixed-point tools

Initial value: Expression

Limit range

Minimum: Maximum:

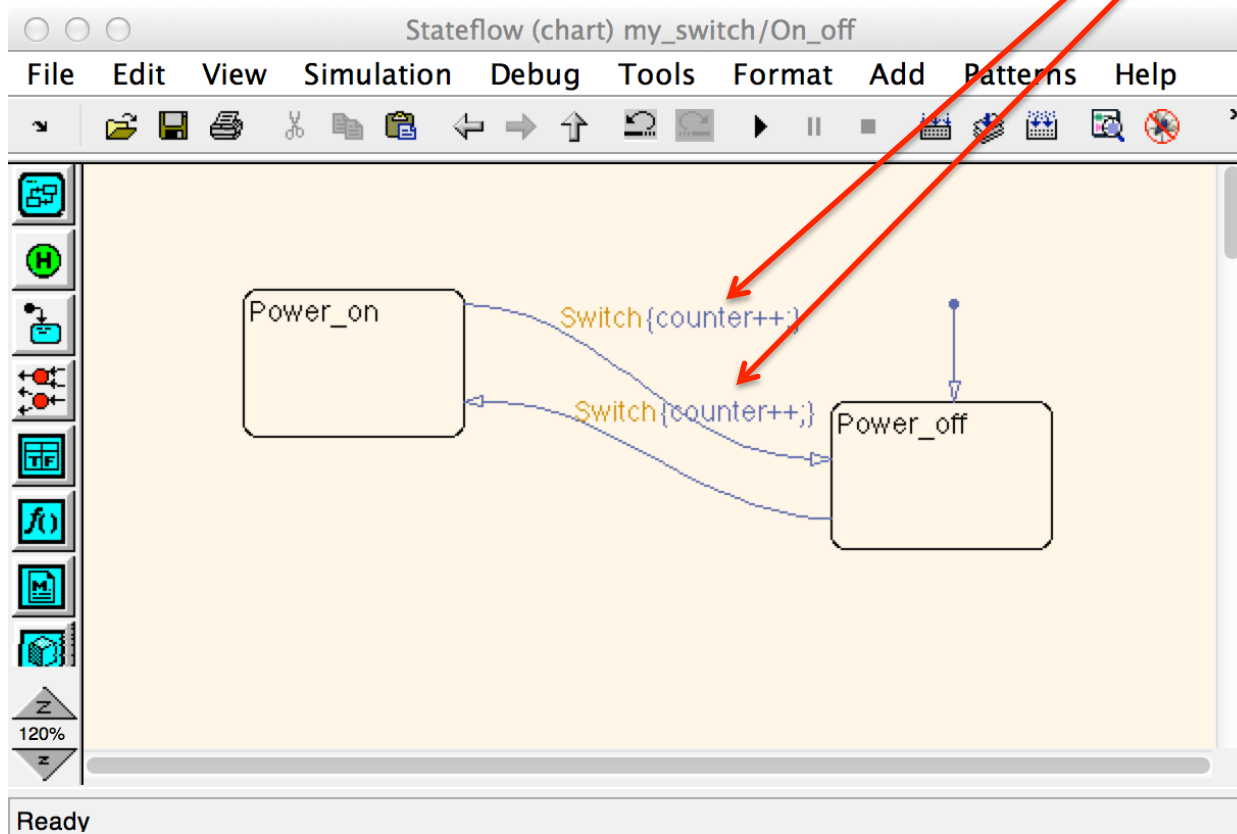
☐ Watch in debugger

OK Cancel Help Apply



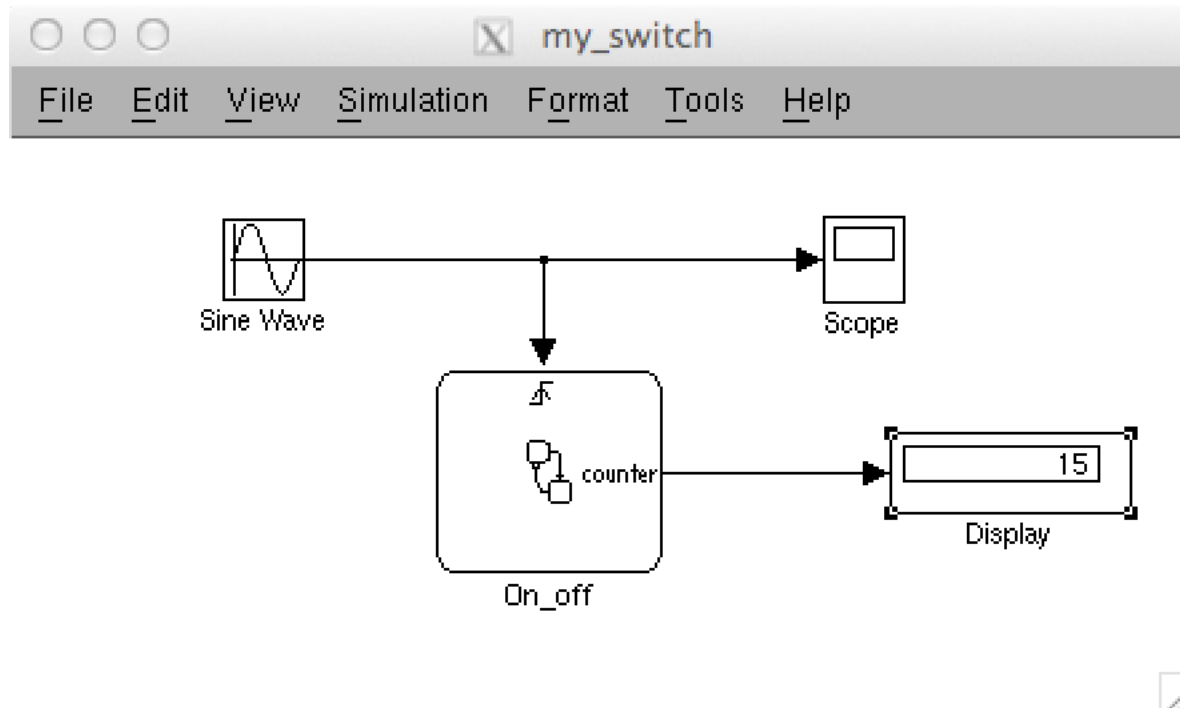
# Increment the Counter

- Increment the counter every time the event “Switch” occurs by placing “counter++” in curly braces following each occurrence of Switch
- Don’t forget to use a semicolon to prevent the value of counter from being printed to the screen each time it is incremented.



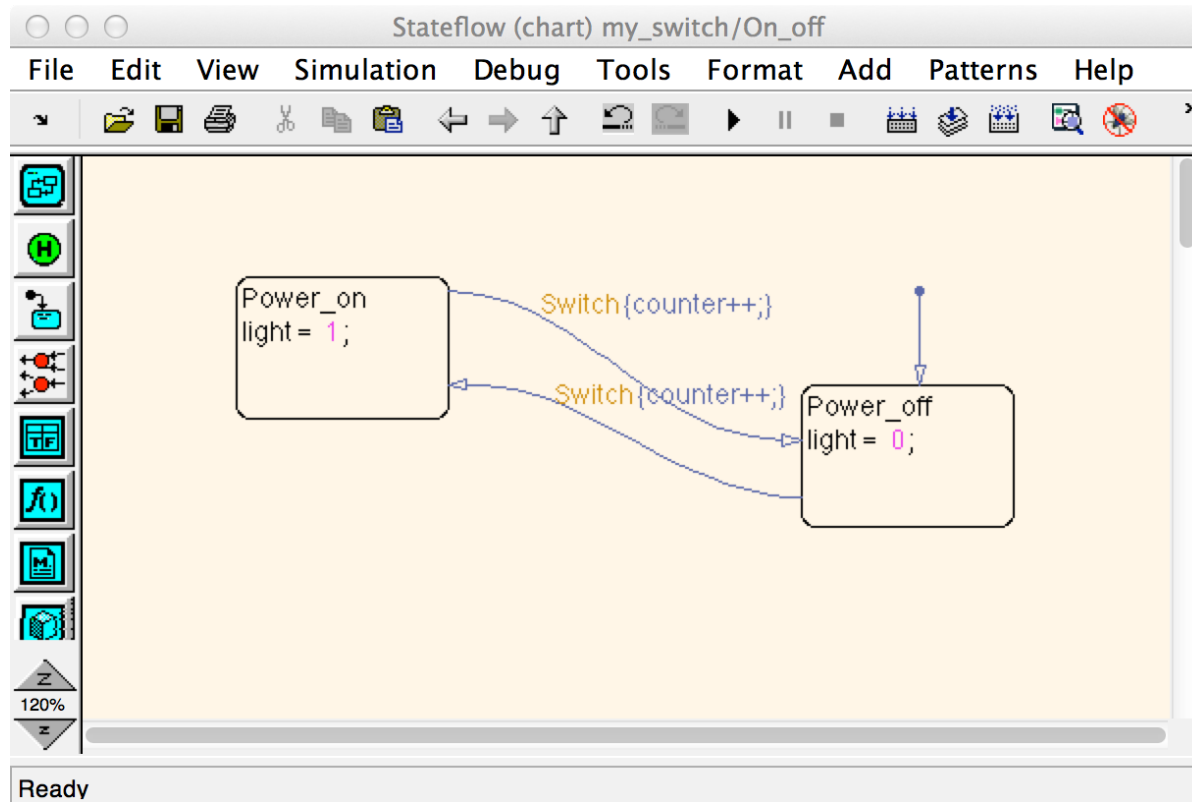
# Count the Transitions

- Add a display block from the View/Library Browser/Sinks menu



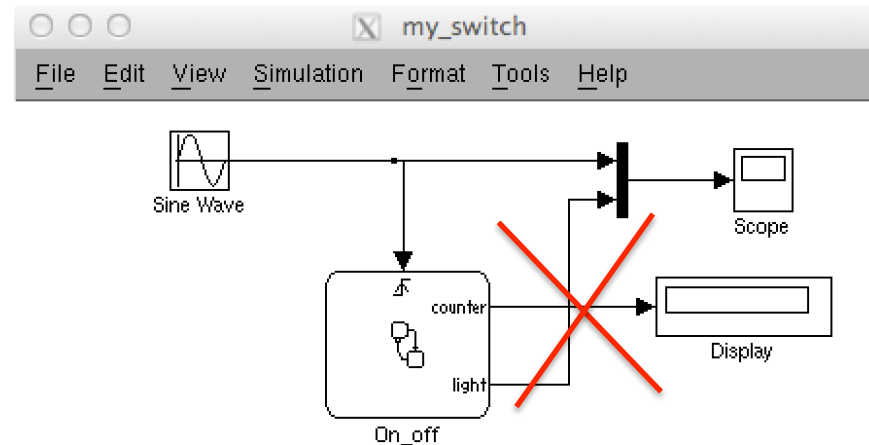
# Toggle a Bit

- Add a new data variable “light”: initial value 0, data type double
- Set “light = 0;” in the Power\_off state
- Set “light = 1;” in the Power\_on state



# Change Port Values

- The output “light” is assigned port 2 by default
- To connect it to the scope requires signal flow lines to cross → bad modeling practice.
- To make model more readable, change port value for “light” from 2 to 1
- Note port value for “counter” is now 2



Model Explorer

Search

Contents of: my\_switch/On\_off

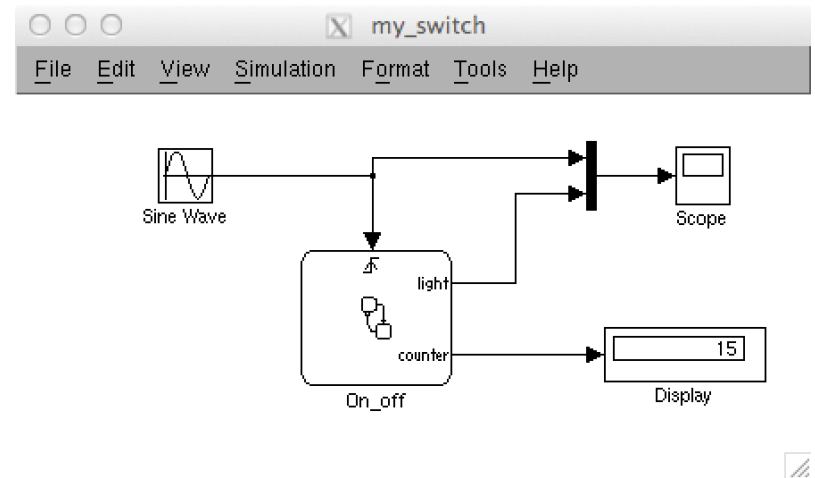
Column View: Stateflow [Show Details](#) [6 of 8 object\(s\)](#)

| Name              | Scope  | Port | Resolve Signal           | DataType | Size | InitialValue | CompiledType | CompiledSize | Trigge |
|-------------------|--------|------|--------------------------|----------|------|--------------|--------------|--------------|--------|
| Switch            | Input  | 1    |                          |          |      |              |              |              | Rising |
| Switch{counter... |        |      |                          |          |      |              |              |              |        |
| Switch{counter... |        |      |                          |          |      |              |              |              |        |
| ?                 |        |      |                          |          |      |              |              |              |        |
| counter           | Output | 2    | <input type="checkbox"/> | double   |      | 0            | double       | 1            |        |
| light             | Output | 1    | <input type="checkbox"/> | double   |      |              | double       | 1            |        |

Contents Search Results

# Display a Square Wave

- Connect the output “light” to the scope used to display the sine wave using a “Mux” block from the Library Browser/Signal Routing Menu



- Running the simulation shows a square wave that toggles between 0 and 1 at rising zero crossings of the sine wave
- To make thicker lines on the plots, double-click the Scope. In the Parameters/Graphics menu, set linewidths to 2.

