6.094 Introduction to MATLAB®
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Introduction to Programming in MATLAB®

Lecture 5: Simulink®

Sourav Dey
Danilo Šćepanović
Ankit Patel
Patrick Ho

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What is Simulink?

- A model-based equation solver
- Some analysis packages (ANSYS, Multisim) have built in equations modeling complex engineering problems.
  - Save lots of time
  - Can only be used for tackling specific problems
- Simulink lets you build a GUI-based model and simulates the result.
  - Unlimited complexity (constrained by runtime and memory)
  - Adaptable for any field
  - Downside? You have to do the modeling work

Getting Started

- Create a new file
- Examine the Simulink Library Browser
  - Click on a library: “Sources”
  - Drag a block into Simulink: “Constant”
  - Visualize the block by going into “Sinks”
  - Drag a “Scope” into Simulink

Connections

- Click on the carat/arrow on the right of the constant box

- Drag the line to the scope
  - You'll get a hint saying you can quickly connect blocks by hitting Ctrl
  - Connections between lines represent signals

- Click the play button

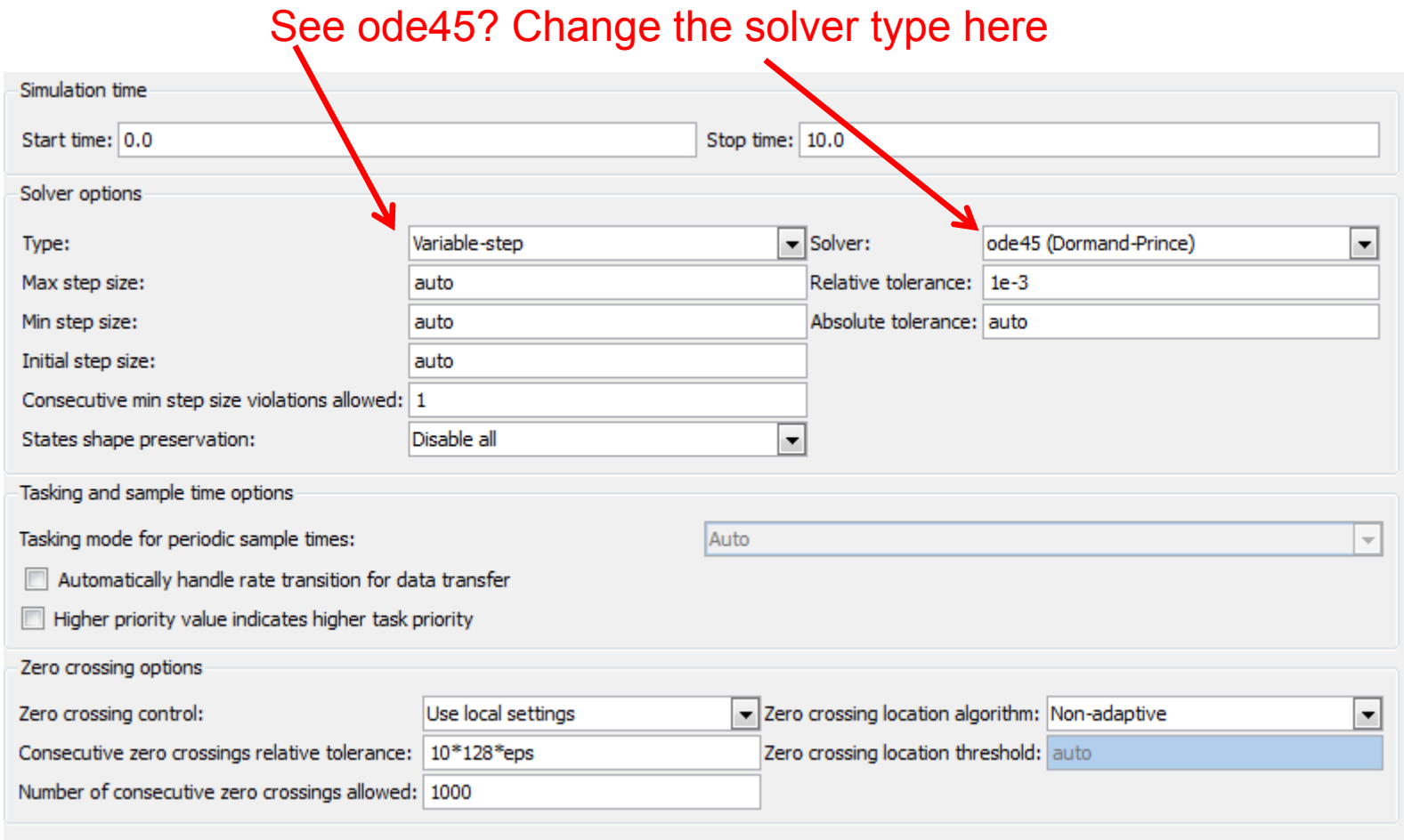
- Double click on the scope.
  - This will open up a chart of the variable over the simulation time

Simulink Math

- Everything is visual in Simulink!
- Click on the library Continuous
  - Drag the integrator block between the constant and the scope
- Play and click on scope.
- What happens?
  - Simulink has a built in ODE solver
  - The equation that represents your model is solved by Simulink
  - We've represented $\int_0^x dx$

Behind the curtain

- Go to "Simulation"->"Configuration Parameters" at the top menu



So what's going on?

- The toolboxes Simulink provides you are full of modeling tools

- By selecting components that correspond to your model, you can design a simulation

Toolboxes

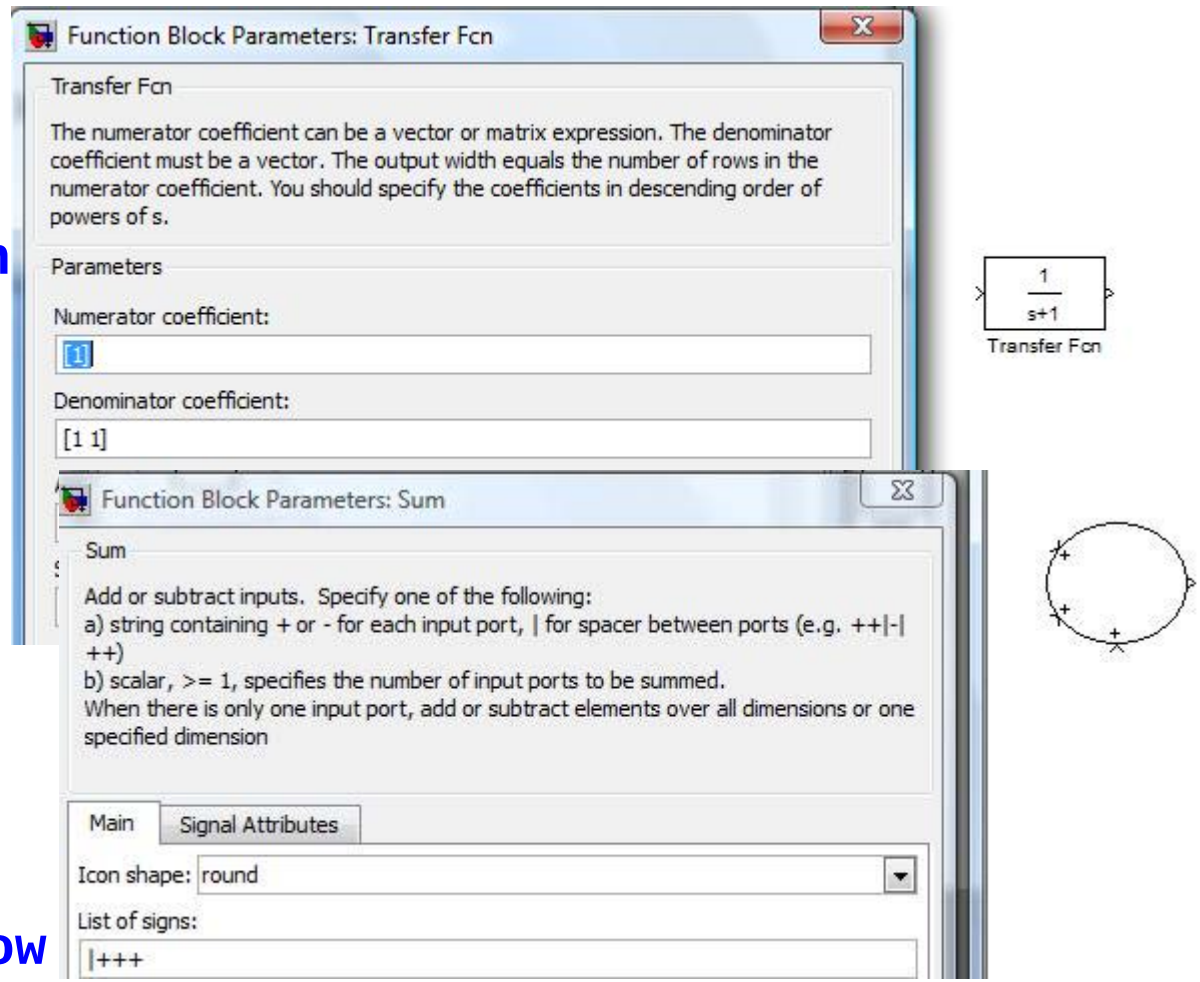
- Math
  - Takes the signal and performs a math operation
  - » **`Add, subtract, round, multiply, gain, angle`**
- Continuous
  - Adds differential equations to the system
  - » **`Integrals, Derivatives, Transfer Functions, State Space`**
- Discontinuities
  - Adds nonlinearities to your system
- Discrete
  - Simulates discrete difference equations
  - Useful for digital systems

Building systems

- Sources
  - **Step input, white noise, custom input, sine wave, ramp input,**
    - Provides input to your system
- Sinks
  - **Scope: Outputs to plot**
  - **simout: Outputs to a MATLAB vector on workspace**
  - **MATLAB mat file**

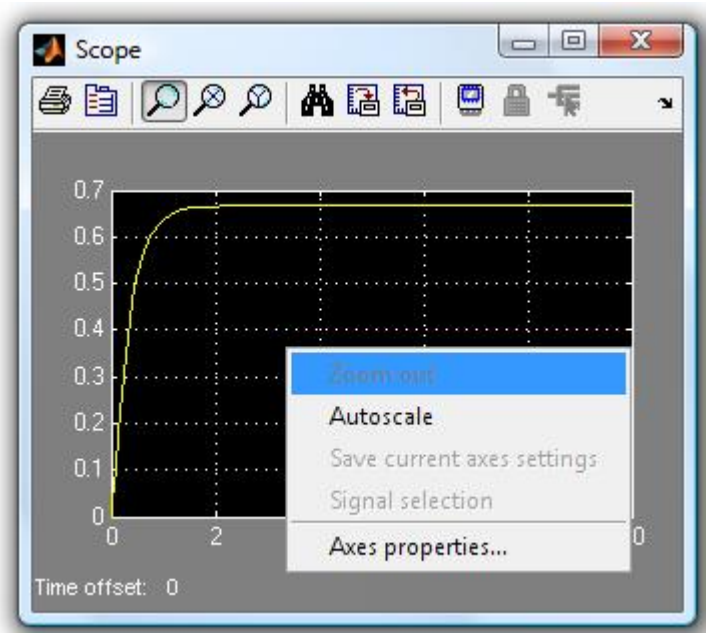
Modifying Blocks

- Right click on the block, select the “Parameters” item corresponding to the item type
- Transfer Function:
  - » **Numerator on first row**
  - » **Denominator on second row**
- Summing Junction:
  - » **List of signs determines inputs to junction**
  - **Not shown: Sampling time row**



Modifying Scopes

- Within the scope:
  - » **Autoscale fits the axes to the curve automatically**
  - » **Axes properties lets you customize the axes**



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- Changing the number of axes:
  - » **Left click on**  **icon**

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  - » **Change the number of axes field**

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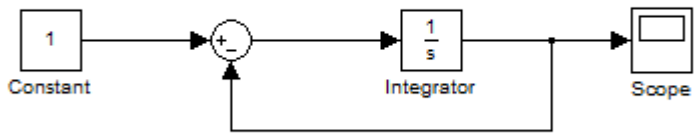
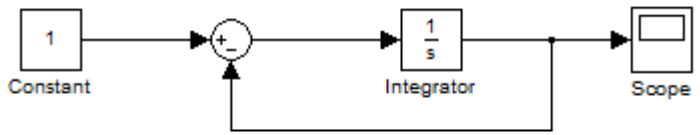
First System

- Drag a summing junction between the constant and integrator
- Change the signs to |+-
- Click on the open carat under the minus sign and connect it to the integrator output

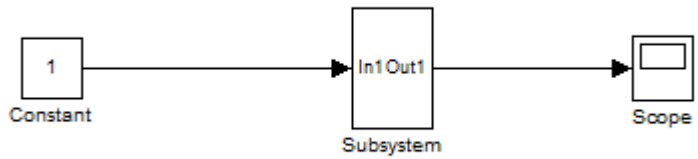


Creating Subsystems

- Drag a box around the parts of the subsystem
  - Summing Junction
  - Integrator
- Right click and select "create subsystem"



- Double click the subsystem:
  - The parts are now inside

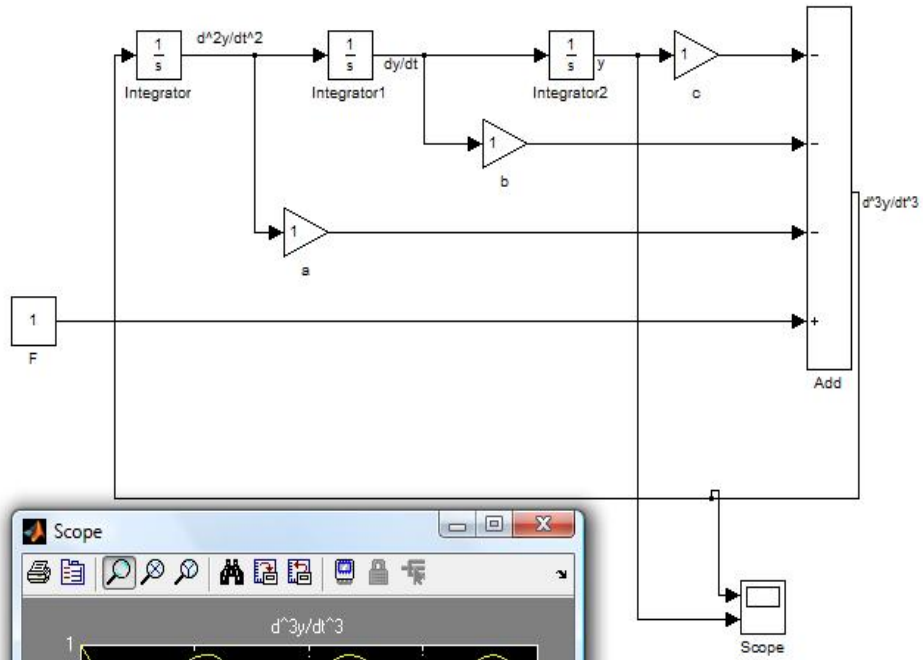


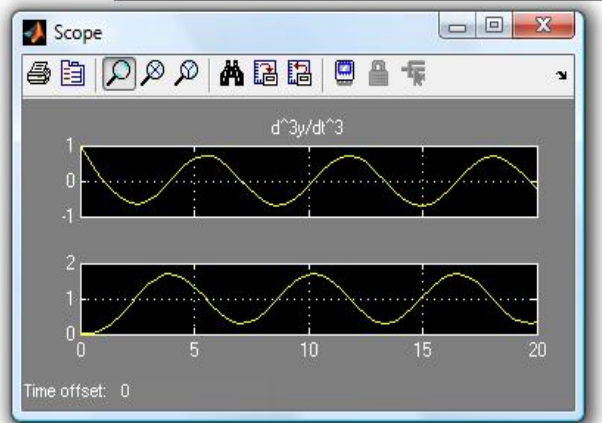
- What's the system do when you run it?

Example Systems

ODE

$$d^3y/dt^3 + a*d^2y/dt^2 + b*dy/dt + c*y = F$$





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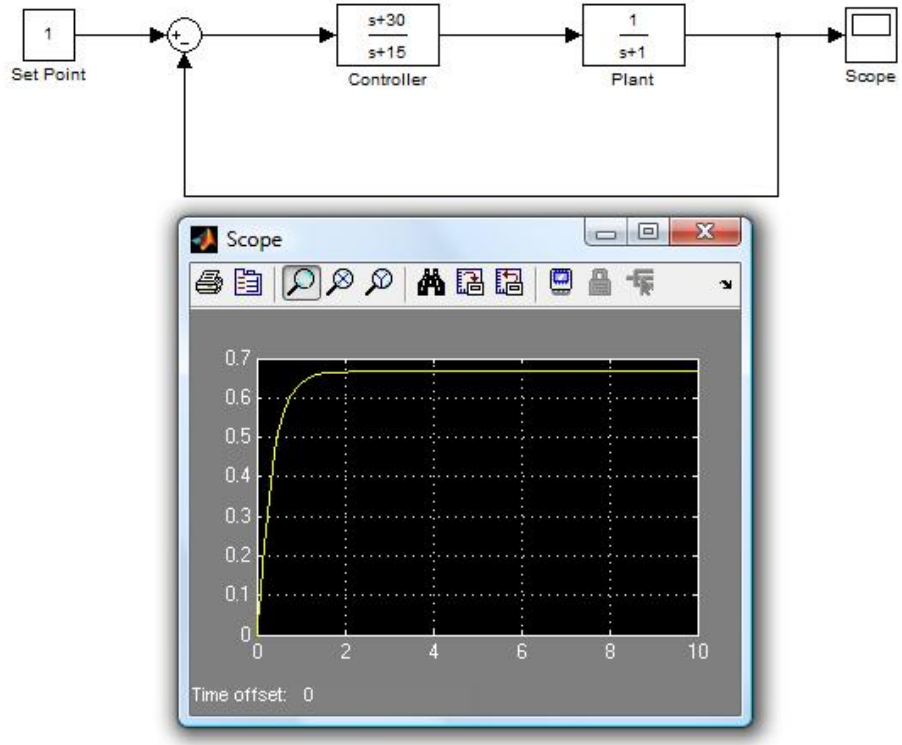
Classical Control System



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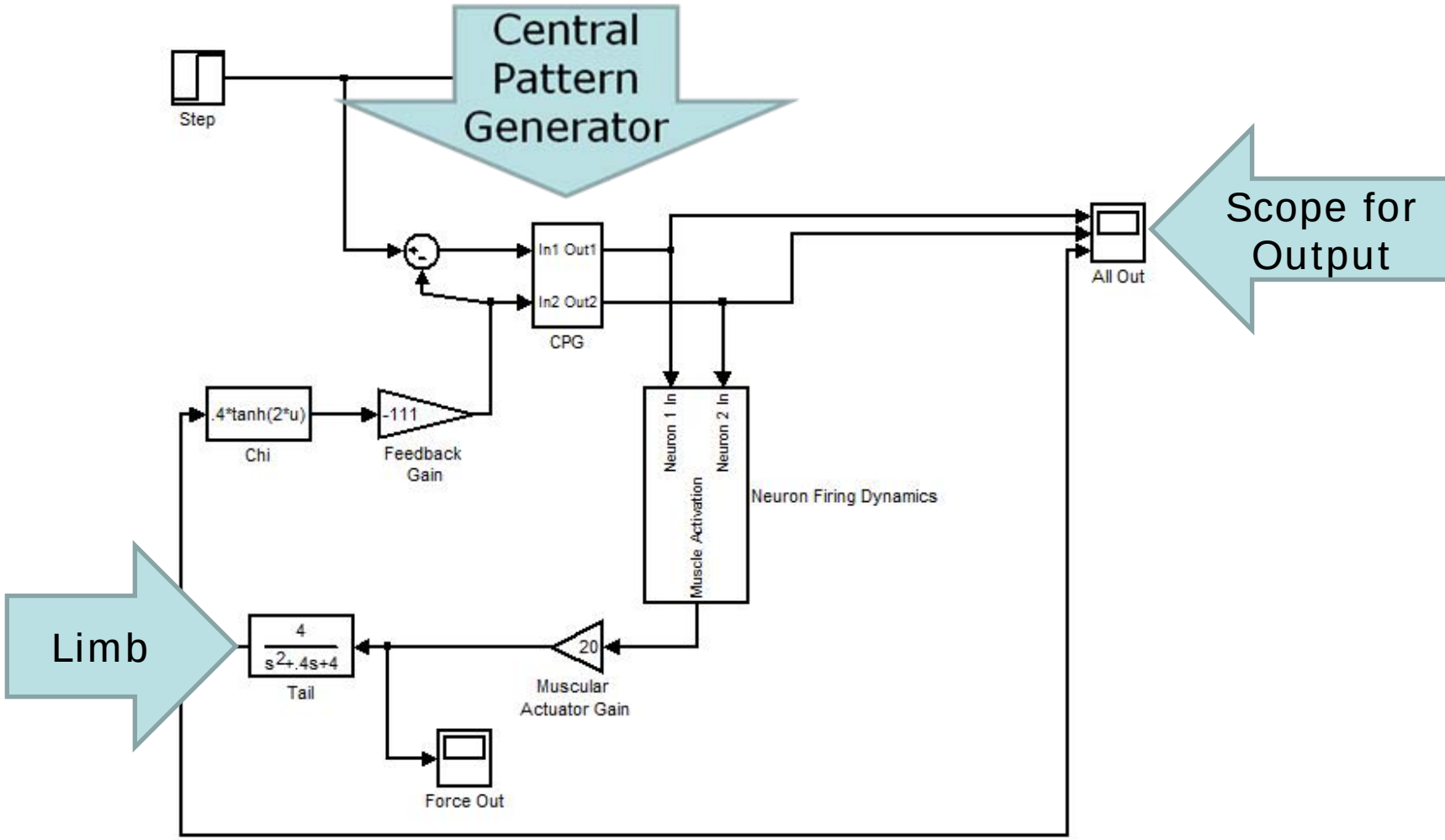
Example: Nervous System

- Neural circuits in animals often exhibit oscillatory behavior
- Use Simulink to model one behavior of this type:
  - Locomotion
    - Limbs go “Left-right, left-right, left-right”
- Locomotive behaviors are generated by “central pattern generators,” which oscillate on their own naturally
- When connected to an appendage, the central pattern generator will adapt its frequency and move the appendage. Open “RIOCPGDemo.mdl”
- Model based on Iwasaki, T., Zheng, M. (2006a). Sensory feedback mechanism underlying entrainment of central pattern generator to mechanical resonance. *Biological Cybernetics, 94*(4), 245-261

Central Pattern Generator Model



Playing with the model

- Look at scopes
  - What are the output signals?
- Delete signals
  - Especially the signal after the feedback gain
- Change gains
  - Muscular actuator gains
  - Switch feedback gain from negative to positive
- Look inside subsystems
  - What's inside the CPG?
  - What's inside the neuron firing dynamics?

Toolboxes

- Simulink has many advanced toolboxes
  - Control Systems
  - Neural Networks
  - Signal Processing
  - SimMechanics
  - Virtual Reality
  - Real Time

- Hopefully you'll get to use some of these powerful tools!