Block Diagrams and Simlink / VisSim

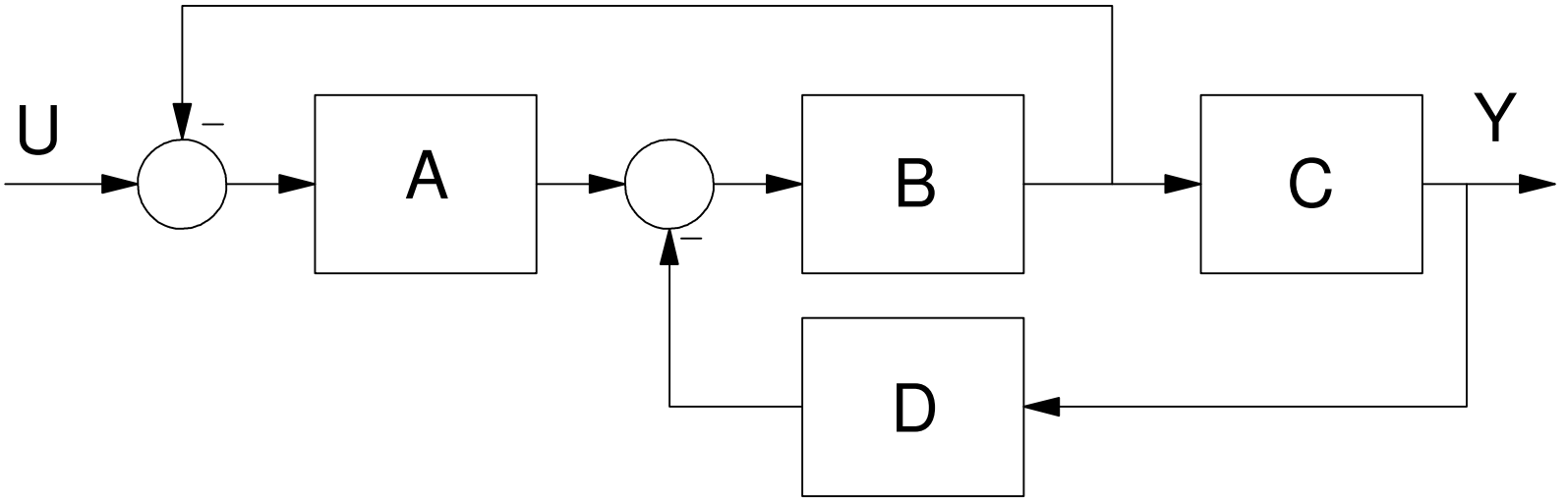
ECE 461/661 Controls Systems

Jake Glower - Lecture #12

Please visit Bison Academy for corresponding
lecture notes, homework sets, and solutions

Block Diagrams

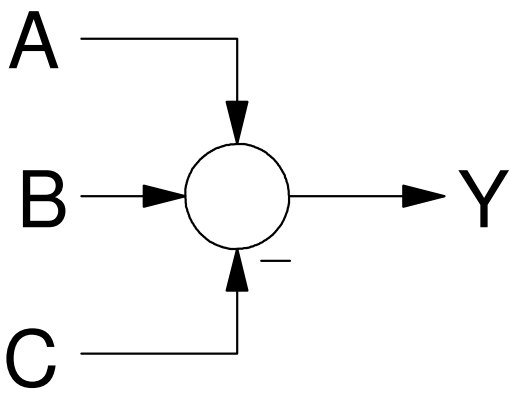
- Graphical way to describe a dynamic system
- Easier to see how systems connect



Symbols

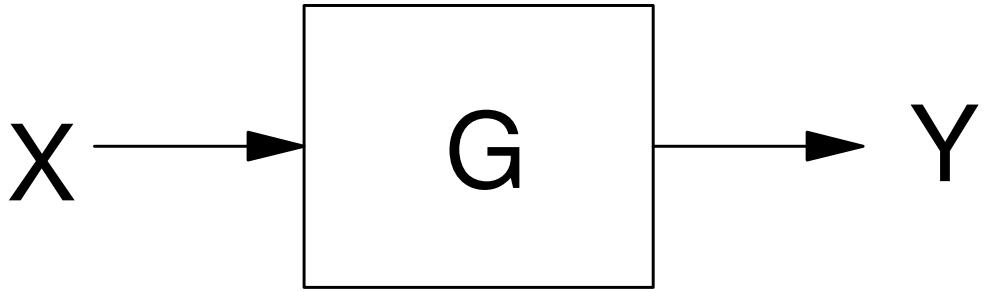
Summing Junction

Y = A + B - C



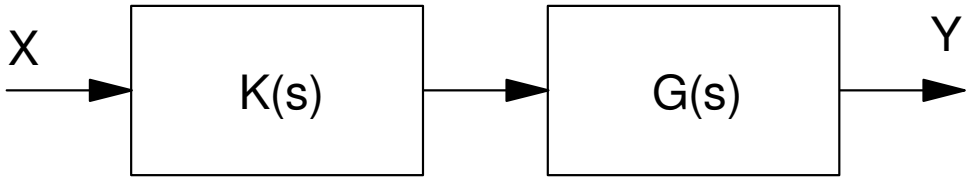
Gain

Y = G(s) X



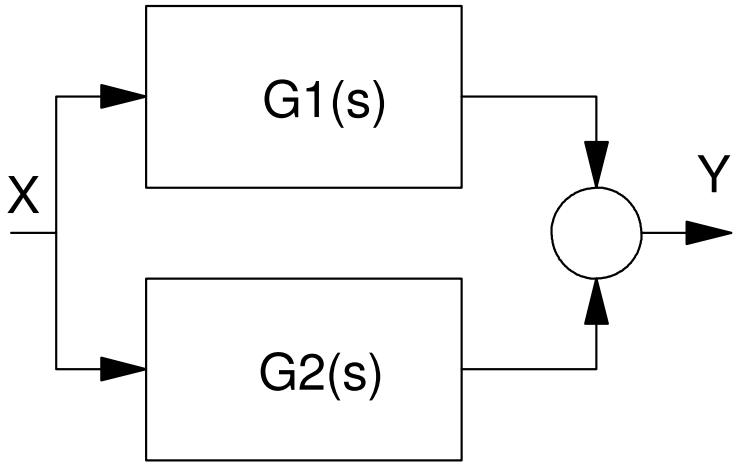
Cascaded Systems

$$Y = (G K) X$$



Parallel Systems

$$Y = (G1 + G2) X$$

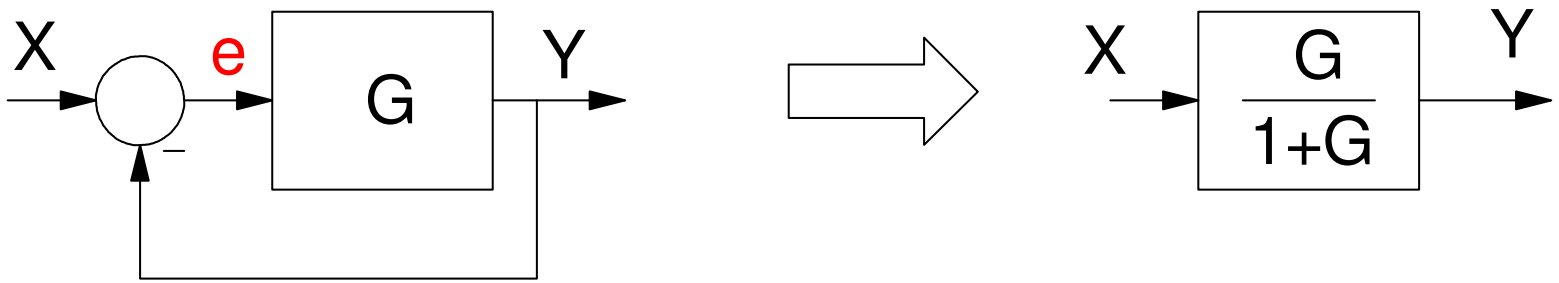


Feedback:

$$Y = Ge$$

$$e = X - Y$$

$$Y = \left(\frac{G}{1+G}\right)X$$



General Case:

Option #1 (always works)

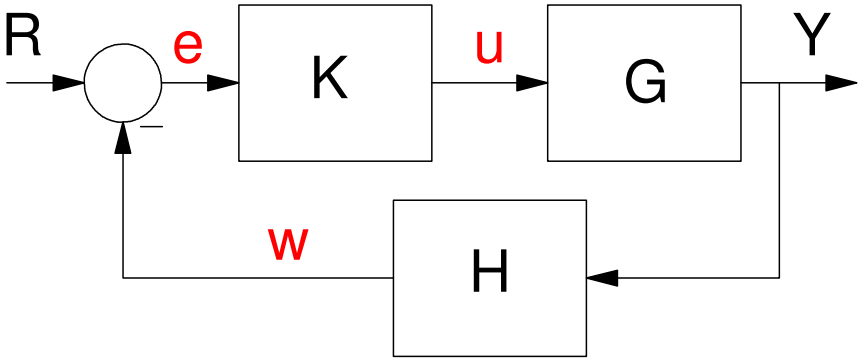
- Assign dummy variables to each output
- Write N equations and solve for N unknowns.
- Solve (this takes a while)

Option #2 (almost always works)

- Write the transfer function by inspection as:

$$\left(\frac{\text{Gain from input to output}}{1+\sum \text{loop gains}} \right)$$

Example #1: Simplify the block diagram



Option #1

$$Y = G\,u$$

$$u = K\,e$$

$$e = R - w$$

$$w = H\,Y$$

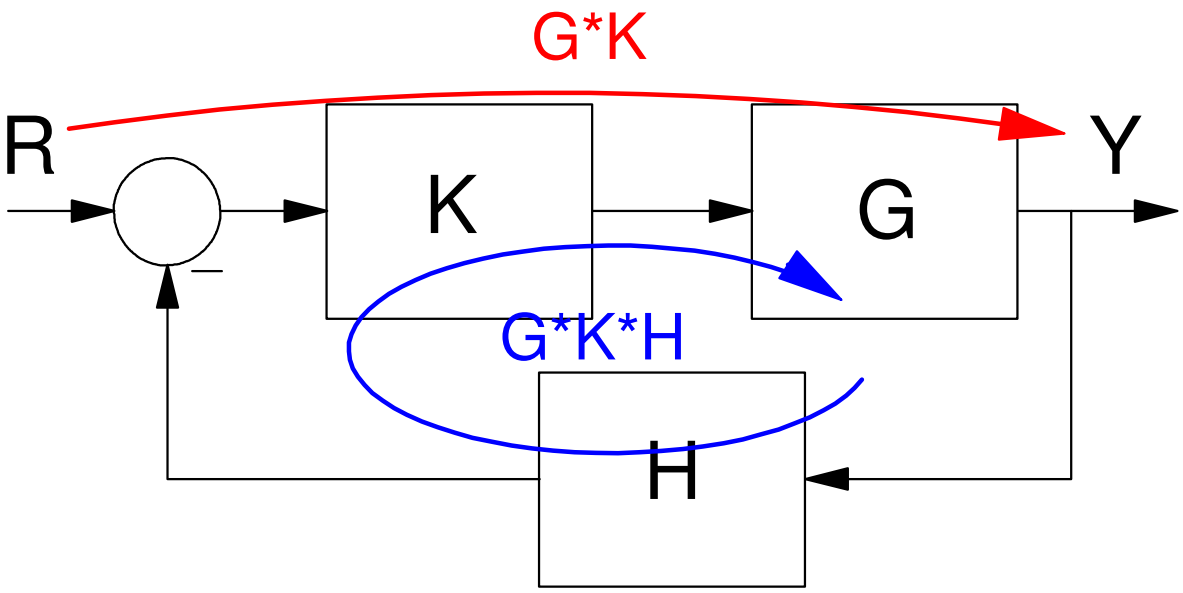
20 minutes later...

$$Y = \left(\frac{GK}{1+GKH}\right)R$$

Option #2:

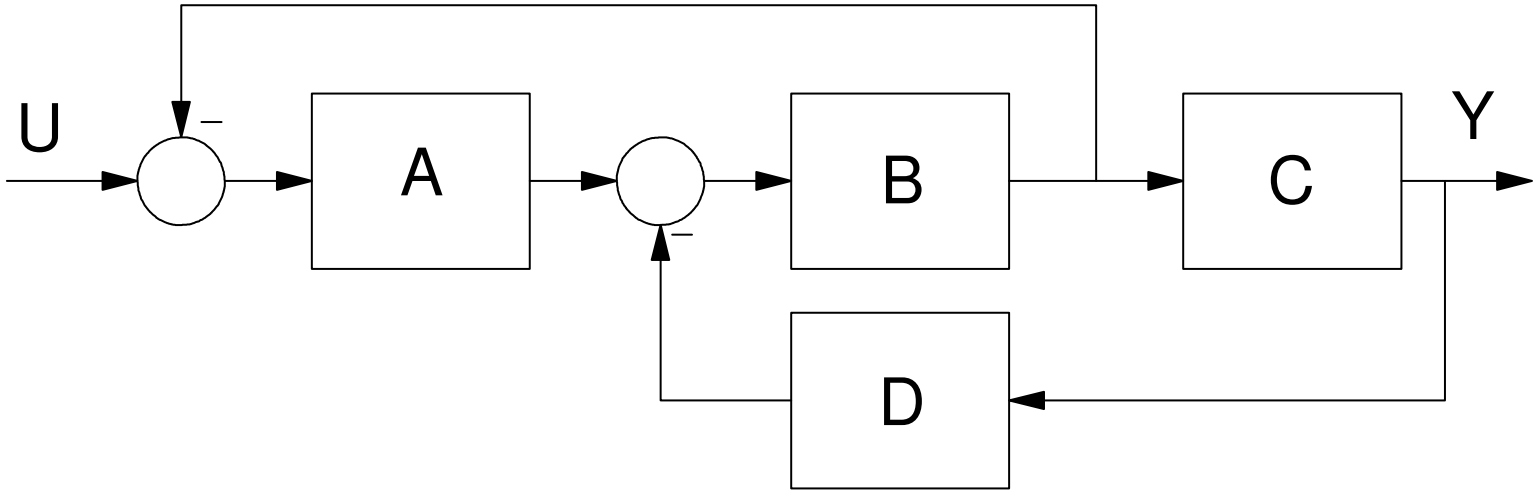
By inspection:

$$Y = \left(\frac{GK}{1+GKH}\right)R = \left(\frac{\text{Gain from input to output}}{1+\sum \text{loop gains}}\right)R$$



Example 2:

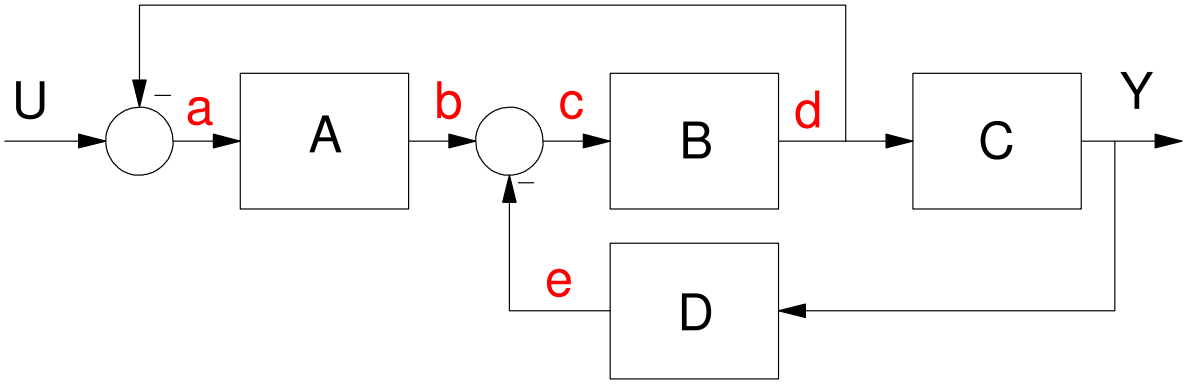
Find the transfer function from U to Y



Option #1: Label everything

- 6 unknowns
- 6 equations

```
a = U - d
b = A a
c = b - e
d = B c
Y = C d
e = D y
```



Solve and in about 20 minutes you'll get the answer.

$$Y = \left(\frac{ABC}{1+AB+BCD} \right) U$$

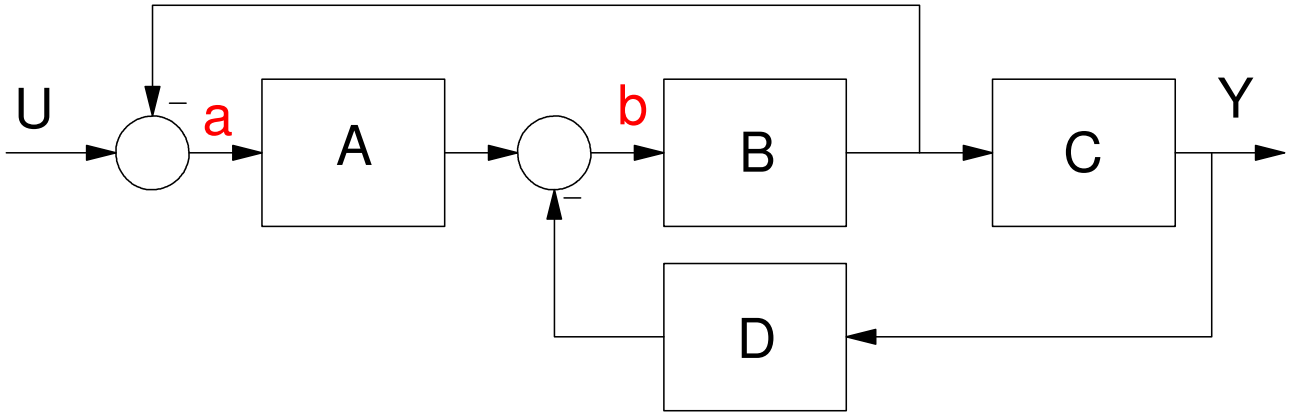
Method 1: (Simplified)

- Just label the output of the summing junction.
- 3 unknowns
- 3 equations

$$a = U - Bb$$

$$b = Aa - DY$$

$$Y = CB\ b$$



Solving

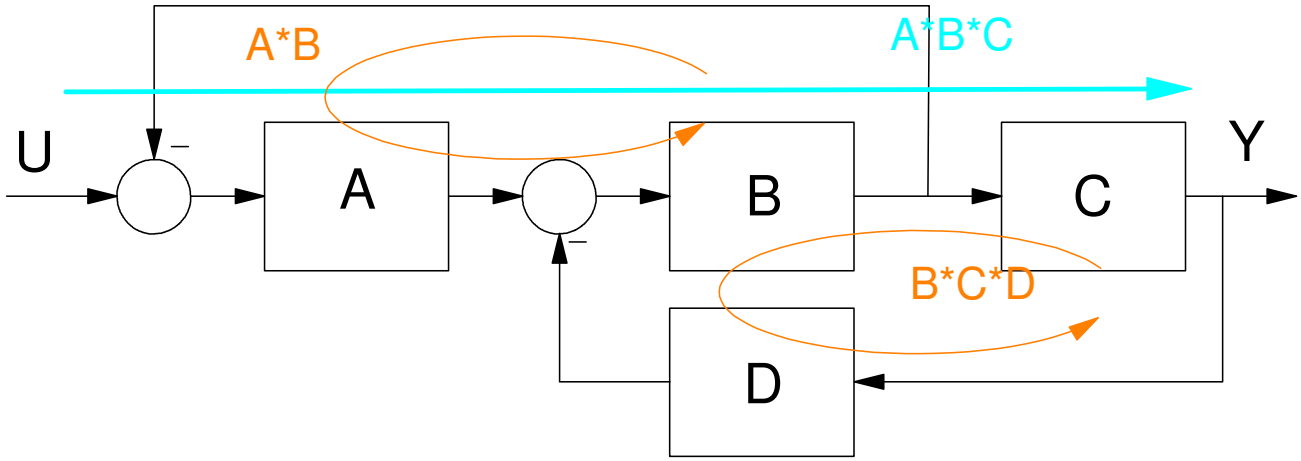
$$Y = \left(\frac{ABC}{1+AB+BCD}\right) U$$

Method #2: Use the shortcut

$$G(s) = \left(\frac{\text{Gain from input to output}}{1 + \sum \text{loop gains}} \right)$$

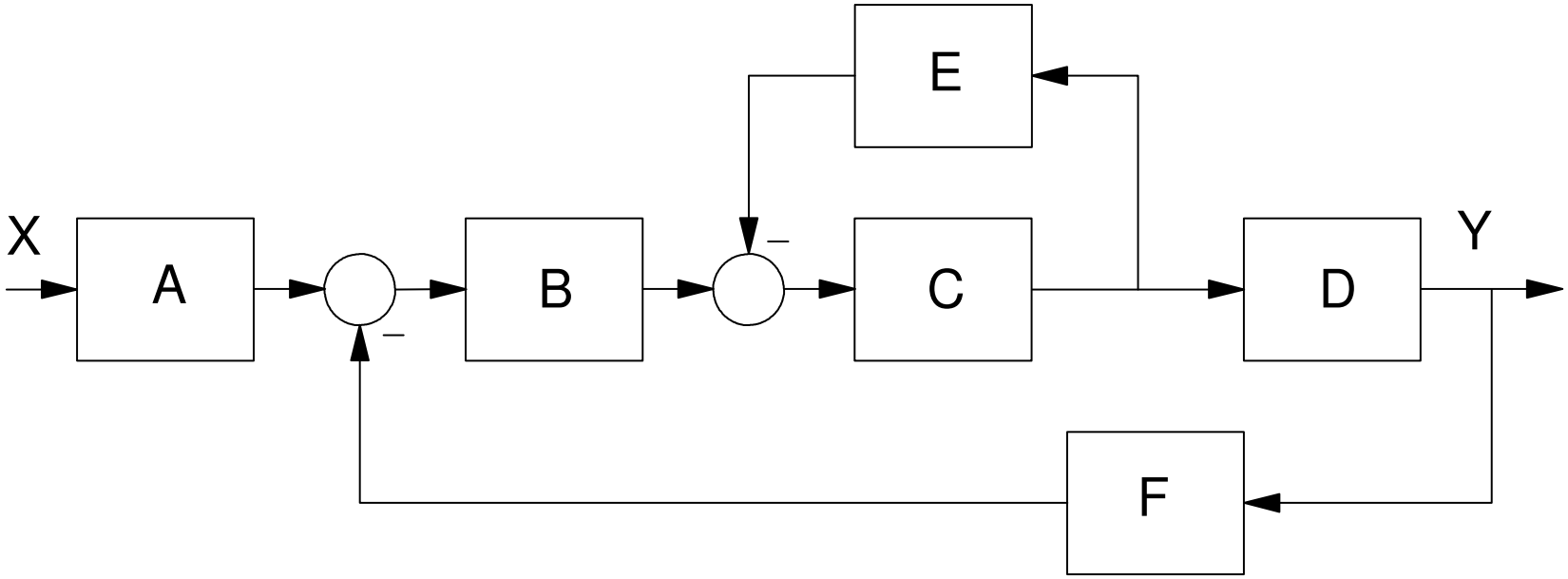
By inspection

$$Y = \left(\frac{ABC}{1+AB+BCD} \right) U$$



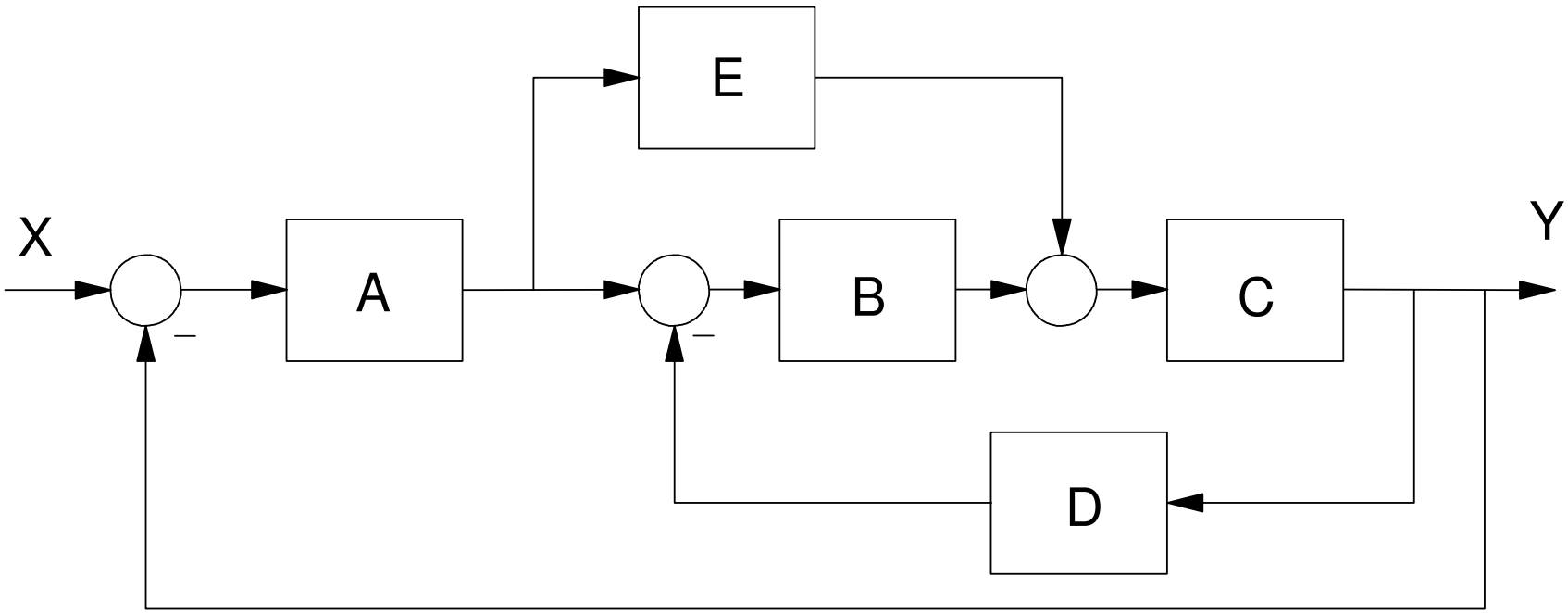
Handout Problem #1

Find the transfer function from X to Y:



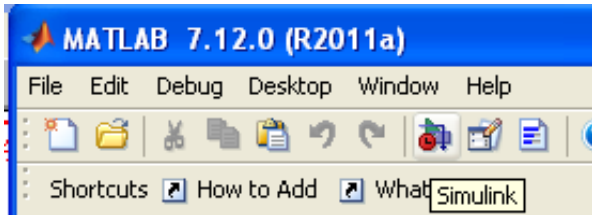
Handout Problem #2

Find the transfer function from X to Y



VisSim / Simulink

- Graphical tools (drag and drop)
- Simulate dynamic systems

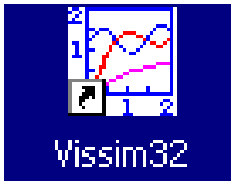


Simulink:

- Mathwork's version
- Should be available on any computer at NDSU with Matlab
- (NDSU has a site licence for both Matlab and Simulink)

VisSim

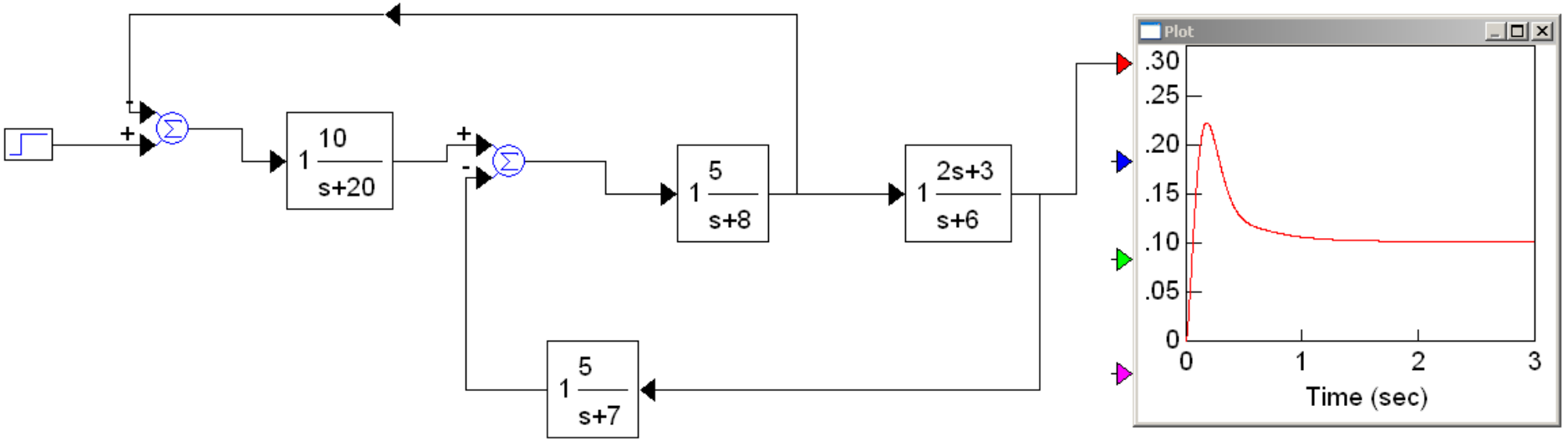
- Predates Simulink (1991)
- Available on-line for free
- Intuitive & friendly
  - There is a user's manual.
  - I've never read it - don't need to.



Block Diagram Simulation

Find the step resopnse

- Easy with Simulink / VisSim (VisSim shown here)

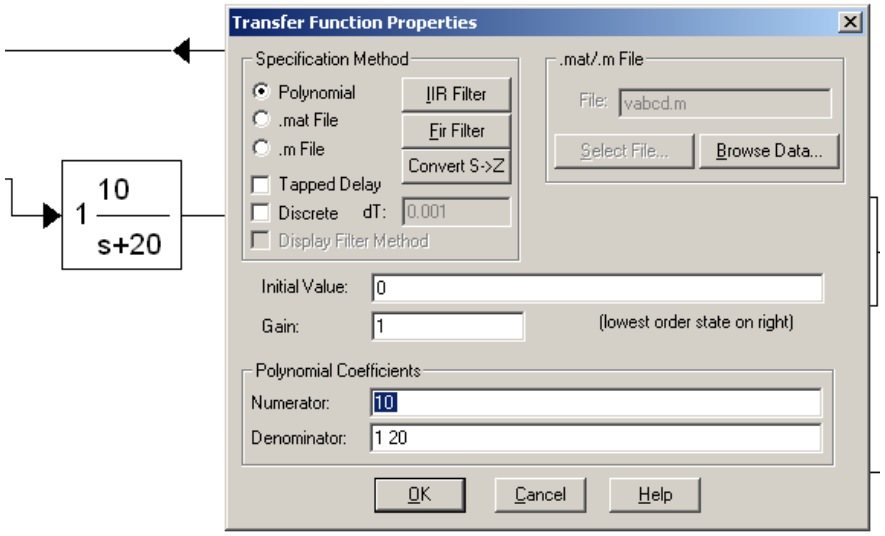


Using VisSim

- Simulink is similar

Uses pull-down menus

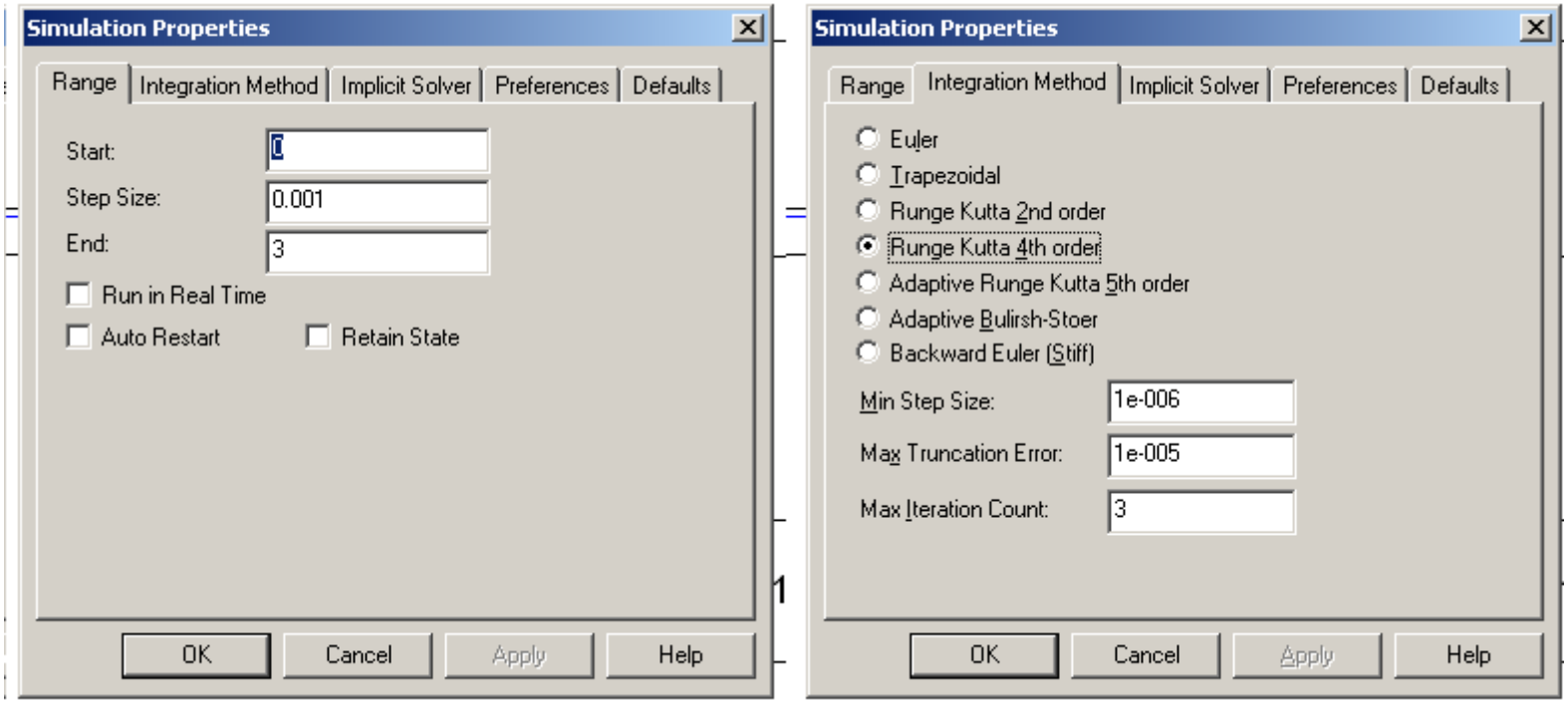
- Search for what you want
- Step Input: Block / Signal Producer / Step
- Summing Junction: Block / Arithmetic / Summing Junction
  - Control / right click to change the sign on the +/- inputs
- Transfer Function: Block / Linear System / Transfer Function.
  - Double click on the transfer function block.
  - The transfer function is input in decreasing powers of 's'. (s+20) is input as (1 20):



- Plot: Block / Signal Consumer / Plot
- Flipping a block: Select the block, go to Edit / Flip Horizontal

Simulation Properties

- Simulation Time
- Step Size
- Numerical Integration Method
  - I prefer Runge Kutta 4th-order

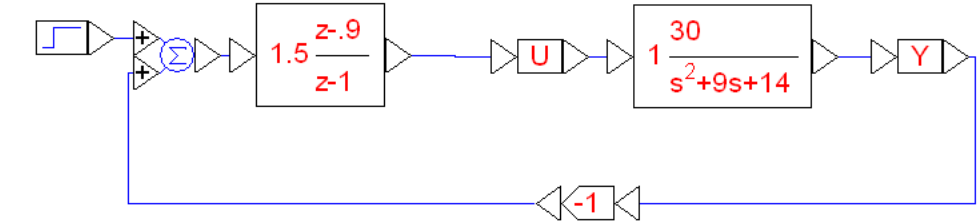


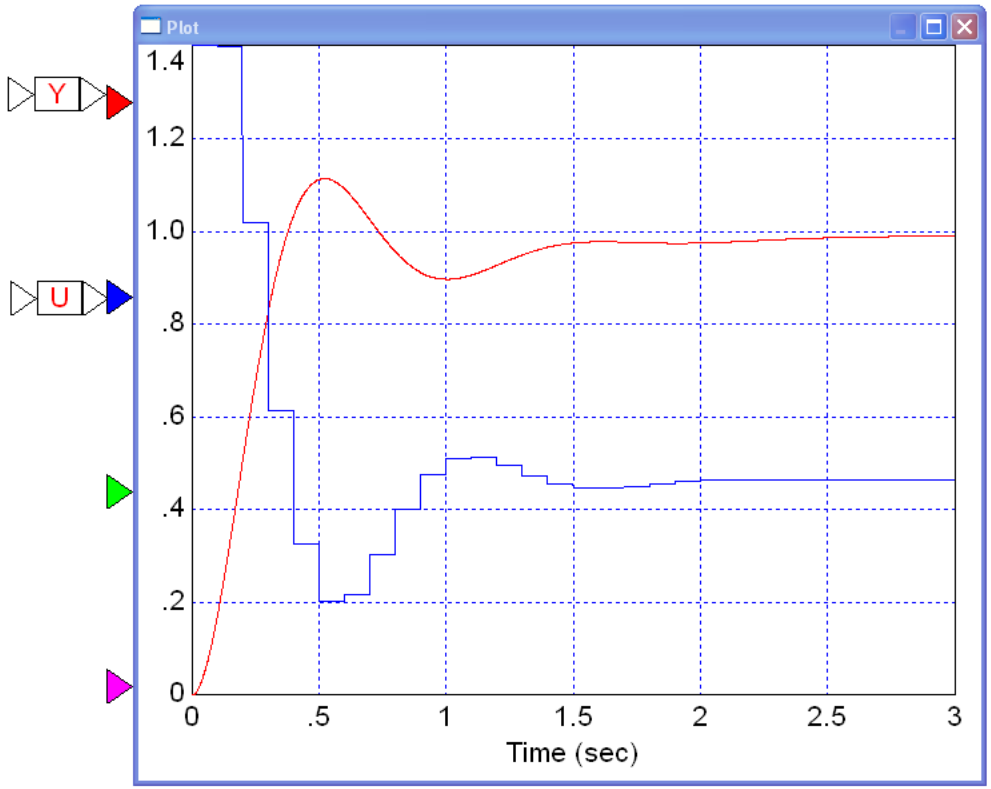
Validating your Homework Solutions:

- Each problem in this class has multiple solutions
- If it works, your answer is correct

Checking you answers

- Simulate the result in VisSim
- Include a screen dump of the simulatio
- Makes grading a *lot* easier





Summary:

Block diagrams are a graphical way of explaining how a system is connected

Using algebra, you can always find the net transfer function

- It can sometimes take a lot of time to do this

This shortcut *usually* works

$$G(s) = \left(\frac{\sum \text{paths from X to Y}}{1+\sum \text{gain around loops}} \right)$$