7- <u>Starting and Stopping a Simulation</u>

To start execution of a model, select **Start** from the model editor's **Simulation** menu or click the **Start** button on the model's toolbar. You can also use the keyboard shortcut, **Ctrl+T**, to start the simulation.
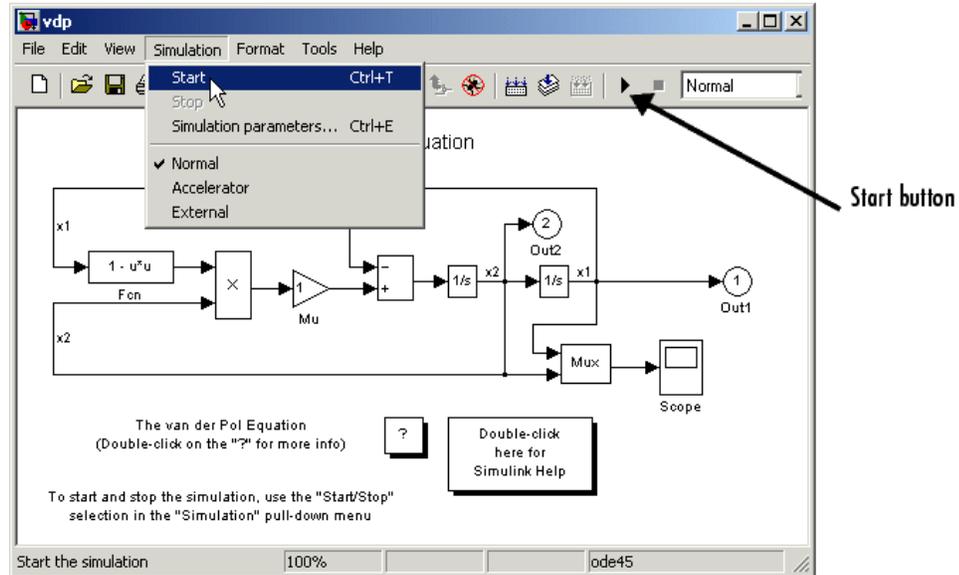
While the simulation is running, a progress bar at the bottom of the model window shows how far the simulation has progressed. A **Stop** command replaces the **Start** command on the **Simulatio**n menu. A **Pause** command appears on the menu and replaces the **Start** button on the model toolbar.

8- <u>Modeling Systems</u>

One of the most confusing issues for new Simulink users is how to model systems. Here are some examples that might improve your understanding of how to model systems.

<u>Example-1: Converting Celsius to Fahrenheit</u>

To model the equation that converts Celsius temperature to Fahrenheit

$$TF = 9/5(TC) + 32$$

First, consider the blocks needed to build the model.
- A Ramp block to input the temperature signal, from the Sources library
- A Constant block to define a constant of 32, also from the Sources library

- A Gain block to multiply the input signal by 9/5, from the Math library
- A Sum block to add the two quantities, also from the Math library
- A Scope block to display the output, from the Sinks library
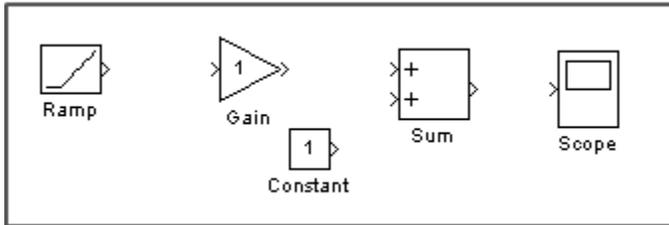
Next, gather the blocks into your model window, assign parameter values to the Gain and Constant blocks by opening (double-clicking) each block and entering the appropriate value. Then, click the **Close** button to apply the value and close the dialog box.

Now, connect the blocks.
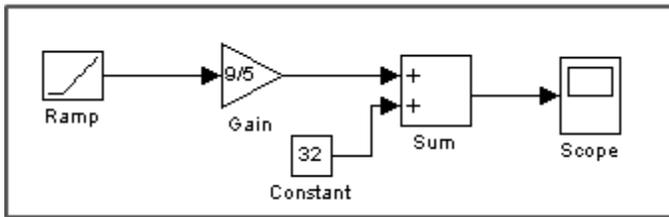
The Ramp block inputs Celsius temperature. Open that block and changes the **Initial output** parameter to 0. The Gain block multiplies that temperature by the constant 9/5. The Sum block adds the value 32 to the result and outputs the Fahrenheit temperature.

Open the Scope block to view the output. Now, choose **Start** from the **Simulation** menu to run the simulation. The simulation runs for 10 seconds.

Example-2: Modeling a Simple Continuous System

To model the differential equation

$$x'(t) = -2x(t) + u(t)$$

where $u(t)$ is a square wave with an amplitude of 1 and a frequency of 1rad/sec. The Integrator block integrates its input x' to produce x. Other blocks needed in this model include a Gain block and a Sum block. To generate a square wave, use a Signal Generator

block and select the Square Wave form but change the default units to radians/sec. Again, view the output using a Scope block. Gather the blocks and define the gain.

In this model, to reverse the direction of the Gain block, select the block, then use the **Flip Block** command from the **Format** menu. To create the branch line from the output of the Integrator block to the Gain block, hold down the **Ctrl** key while drawing the line.
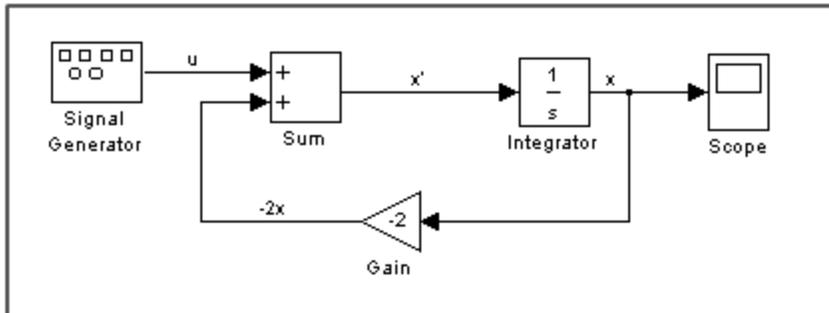
An important concept in this model is the loop that includes the Sum block, the Integrator block, and the Gain block. In this equation, x is the output of the Integrator block. It is also the input to the blocks that compute x', on which it is based. This relationship is implemented using a loop.

The Scope displays x at each time step. For a simulation lasting 10 seconds, the output looks like this:
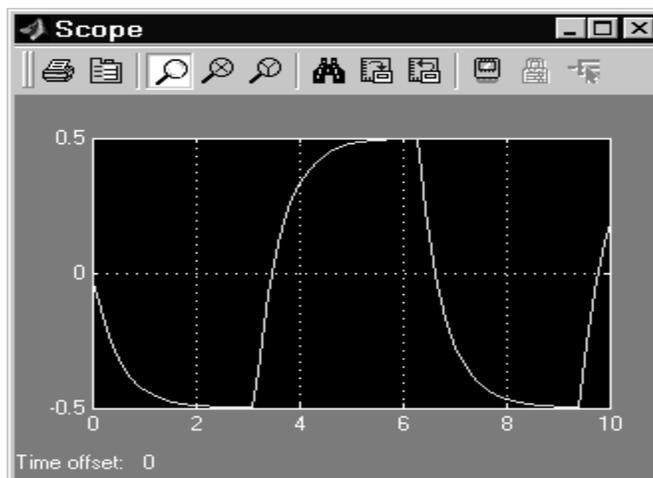
The equation you modeled in this example can also be expressed as a transfer function. The model uses the Transfer Fcn block, which accepts u as input and outputs x. So, the block implements x/u. If you substitute sx for x' in the above equation, you get

$$sx = -2x + u$$

Solving for x gives

$$x = u/(s+2)$$

or,

$$x/u = 1/(s+2)$$

The Transfer Fcn block uses parameters to specify the numerator and denominator coefficients. In this case, the numerator is 1 and the denominator is s+2. Specify both terms as vectors of coefficients of successively decreasing powers of s. In this case the numerator is [1] (or just 1) and the denominator is [1 2]. The model now becomes quite simple.
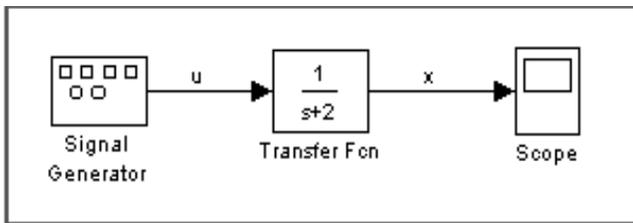
The results of this simulation are identical to those of the previous model.

Example-3: Modeling a Simple Control System

In this example we will model a simple control system and finding its time response according to these specifications:

The Plant Transfer function $(G(s)) = \dfrac{1}{s^2 + 2s + 1}$.

The Feedback Transfer function $(H(s)) = \dfrac{1}{s+1}$.

Note that to find the response for any control system, a step input is usually used.

Assign parameter values to the blocks by opening (double-clicking) each block and entering the appropriate value. Then, click the **Close** button to apply the value and close the dialog box. Now, connect the blocks and view the response from the Scope block:
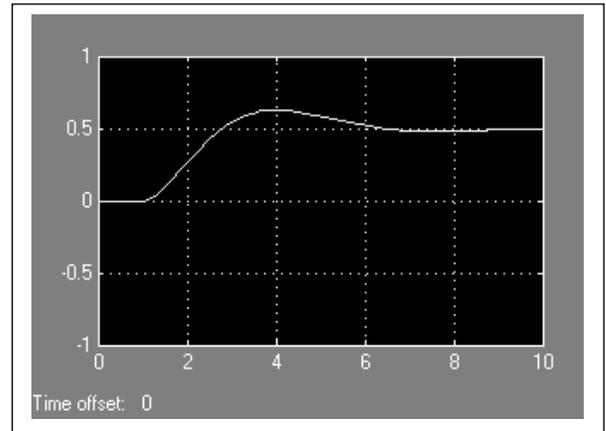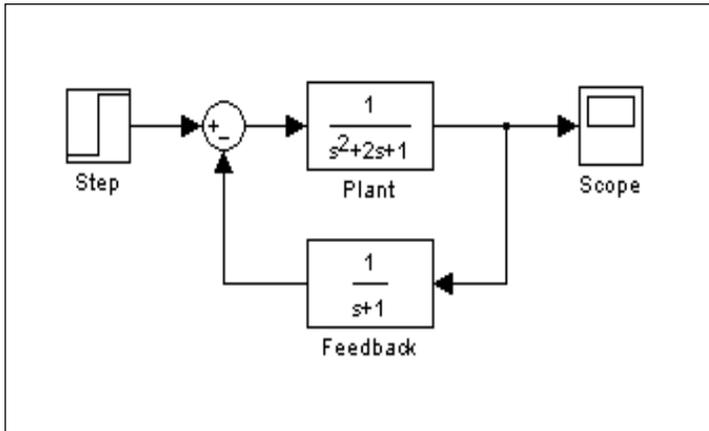
Example-4: Building a Channel Noise Model:

This section shows how to build a simple model of a communication system. The model, shown in the following figure, contains the most basic elements of a communication system: a source for the signal, a channel with noise, and means of detecting errors caused by noise.
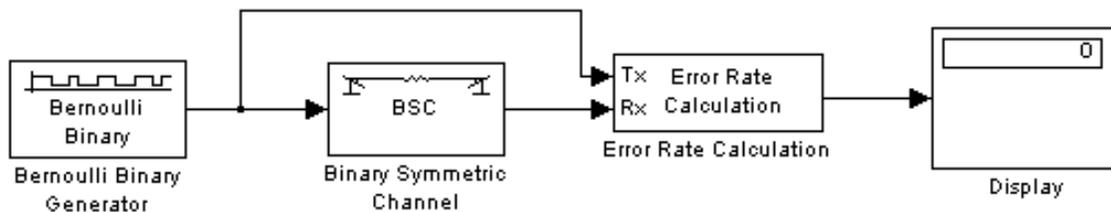
We encourage you to build the model for yourself, as this is the best way to learn how to use the Communications Blockset.

Overview of the Model

The channel noise model generates a random binary signal, and then switches the symbols 0 and 1 in the signal, according to a specified error probability, to simulate a channel with noise. The model then calculates the error rate and displays the result. The model contains the following components.

1. Source: The source for the signal in this model is the Bernoulli Binary Generator block, which generates a random binary sequence. You can get this block from the Data Sources sublibrary of the Comm Sources library.

2. Channel: The Binary Symmetric Channel block simulates a channel with noise. The block introduces random errors to the signal by changing a 0 to a 1 or the reverse, with a probability specified by the **Error probability** parameter in the block's mask. You can get this block from the Channels library.

3. Error Rate Calculation: The Error Rate Calculation block calculates the error rate of the channel. The block has two input ports, labeled Tx, for the transmitted signal, and Rx, for the received signal. The block compares the two signals and checks for errors. The output of the block is a vector with three entries:

- Bit error rate, which you expect to be approximately 0.01, since this is the probability of error in the channel
- Number of errors
- Total number of bits that are transmitted

You can get this block from the Comm Sinks library.

4. Display: The Display block displays the output of the Error Rate Calculation block. You can get this block from the Simulink Sinks library.

Setting Parameters in the Channel Noise Model

To set block parameters in the channel noise model, do the following:

1. Double-click the Binary Symmetric Channel block and set **Error probability** `0.01`.
   Clear the box next to **Output error vector**. This removes the block's lower output port, which is not needed for this model.
2. Double-click the Error Rate Calculation block and set **Output data** to **Port** to create an output port for the block. Select the box next to **Stop simulation** (This causes the simulation to stop after the target number of errors occurs or the maximum number of symbols is reached).

Connecting the Blocks

Next, connect the blocks as shown in the following figure. Make sure to connect the arrow from the Binary Symmetric Channel block to the input port labeled Rx on the Error Rate Calculation block.
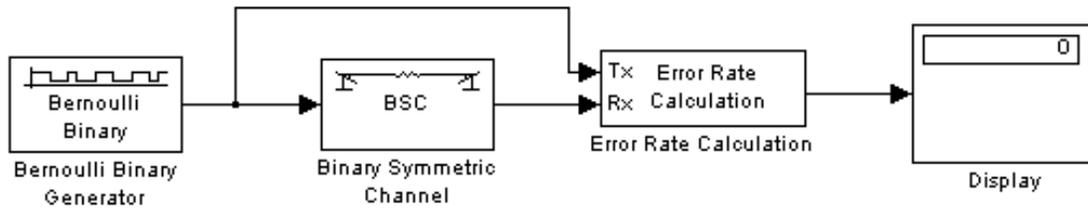
The upper line leading from the Bernoulli Binary Generator block to the Error Rate Calculation block, shown in the following figure, is called a *branch line*. Branch lines carry the same signal to more than one block.

Running the Model

To run the model, select **Start** from the **Simulation** menu. After a few seconds, the model will stop automatically. To see all three boxes in the Display block, you must enlarge the block slightly by Selecting the Display block and move the mouse pointer to one of the lower corners of the block, so that a diagonal arrow appears on the corner, as shown.
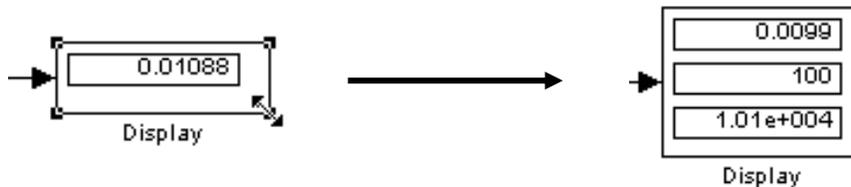
The Display block displays the following information:

- The bit error rate
- The number of errors
- The total number of bits that are transmitted

Exercises:

1. If a stone is thrown vertically with an initial speed **u**, its vertical displacement **s** after a time **t** has elapsed is given by the formula:

$$s(t) = ut - gt^2/2 \quad \text{(Air resistance has been ignored)}$$

Model this equation with a simulink diagram to obtain a plot for the vertical displacement **s** with time **t**. Where g=9.8 , u=40.

Hints:

First, consider the blocks needed to build the model.

- A Ramp block to input the time signal t, from the Sources library.
- A Math function block (double click on it and select square) to get t^2, from the Math library.
- A Gain block to multiply the input signal by u, from the Math library.
- A Gain block to multiply the square of the input signal by g/2, from the Math library.
- A Sum block to subtract the two quantities, also from the Math library.
- A Scope block to display the output, from the Sinks library.

Next, gather the blocks into your model window. Note that the output will not display a cleared output so right click on the display and select autoscale.

2. If the exact number of bacteria at time t is given by the formula:
$$N(t) = 1000 \ e^{rt}$$

Where r (growth rate per hour)=0.01 and t (in hours) is a ramp input

Model this formula in a simulink diagram to obtain a plot for the bacteria growth (N) with time (t).

Hint:

The blocks needed to build the model.

- A Ramp block to input the time signal t, from the Sources library.
- A Gain blocks to multiply r with t, from the Math library.
- A Math function block to get the exp, from the Math library.
- A Gain blocks to multiply the result×1000, from the Math library.
- A Scope block to display the output, from the Sinks library.

3. Model the differential equation

$$x''(t) = -5x'(t) + 2x(t) + u(t)$$

Where $u(t)$ is a square wave with an amplitude of 1 and a frequency of 1rad/sec. View the output using a Scope block.. **Hint:** See example-2, page (6-13).

4. Repeat problem-3 using the Transfer Fcn block. **Hint:** See example-2, page (6-14).

5. Model the differential equation

$$x''(t) = x'(t)x(t) - 2x(t) + u(t)$$

where $u(t)$ is a sine wave with an amplitude of 1 and a frequency of 10 rad/sec. View the output using a Scope block.. **Hint:** See example-2, page (6-13).

6. Model the following control system and find its time response according to these specifications:

Plant Transfer function $(G(s)) = \dfrac{2}{s^2 + 3s + 1}$, Feedback Transfer function $(H(s)) = \dfrac{2}{s+2}$, A forward gain $(K) = \mathbf{0.1}$, $\mathbf{1}$, and $\mathbf{10}$.

Find the response for this system for each value of the gain (K). Note that to find the response for any control system, a step input is usually used. **Hint:** See example-3.

7. Model the following control system having a plant transfer function $(G(s)) = \dfrac{\omega_n^2}{s^2 + 2\zeta\omega_n s + \omega_n^2}$ and unity feedback transfer function (H(s)). Find the time response according to:

a) $\zeta = 0$ and $\omega_n = 2$.

b) $\zeta = 0.1$ and $\omega_n = 4$.

c) $\zeta = 1$ and $\omega_n = 8$.

8. Build the following communication system model. The model, shown in the following figure, contains the most basic elements of a communication system: a source for the signal, a channel with noise, and means of detecting errors caused by noise.
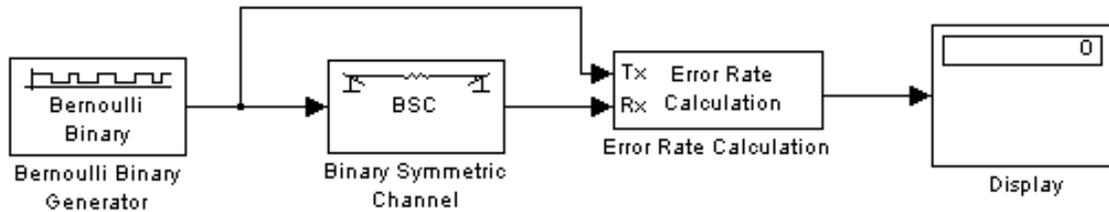
Set the Error probability for the Binary Symmetric Channel Block `0.01, 0.05, 0.1` and `1.0,` and the sampling rate for Bernoulli Binary Generator Block 0.001.

Connect the blocks and display the following information for each value of Error probabilities:

- The bit error rate.
- The number of errors.
- The total number of bits that are transmitted.

Hint: See example-4, page (6-16).

9. Repeat problem-7 but replace the Binary Symmetric Channel Block by the AWGN Channel Block with signal to noise ratio (SNR) equal to 100, 1000, and 10000 dB.

Hint: You can get the AWGN Channel Block from the Channels sublibrary in Communications blockset library and it looks like the figure below. For more information, see example-4, page (6-16).