Use of the LTI Viewer and MUX Block in Simulink

INTRODUCTION

The Input-Output ports in Simulink can be used in a model to access the LTI Viewer. This enables the user to display information about the magnitude and phase distortion (i.e. a Bode plot) between the input and output of a given model. This can be used in conjunction with the MUX block, which allows the user to plot the input and output signals together. These two tools can help the user understand how the system being modeled will distort a signal. In this tutorial, both of these tools will be used to examine how a sine-wave signal is distorted when passed through an RC circuit.

To illustrate these tools, the first-order RC circuit model will be used, with R = 130kΩ, C = 0.2μF, and with the input being a 3 Hz Sine wave with an amplitude of 1.

The basic Simulink model for the first-order RC circuit is shown in Fig. 1 below.

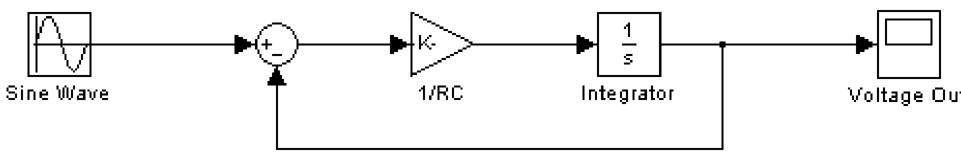

Fig. 1. Basic model of the first-order RC circuit.

USE OF THE MUX BLOCK

If this model is run, the amplitude of the output sine wave is less than that of the input. What is less apparent is that there is also a phase shift. To see both the amplitude change and the phase shift a MUX block will be inserted into the model.

Go to the ***Simulink Library Browser → Signals & Systems***, and drag and drop the ***MUX*** block into the model. Tap one line off the input Sine Wave block and one off the output voltage line; feed both of these signals into the front of the MUX block. The output of the MUX block should then be fed into a Scope as shown in Fig. 2.

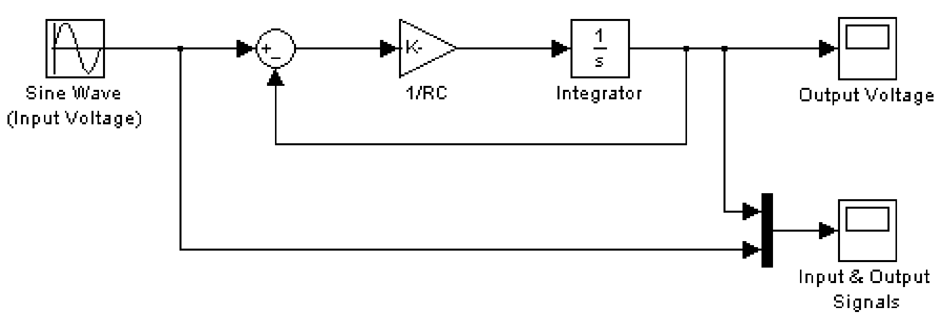

Fig. 2. Model with input and output signals fed through an MUX block.

Run the model, and double-click on the Scope block which is connected to the MUX block. Both the input and output signals will be plotted together as a function of time, as shown in Fig. 3.

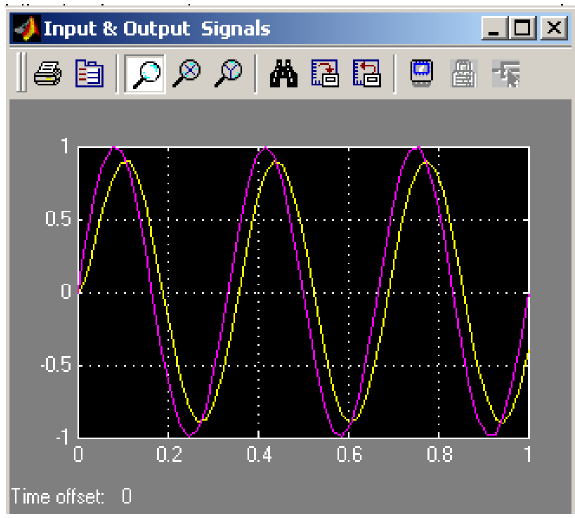

Fig. 3. Input and output voltage plotted together.

It is clear now that there has been both an attenuation of the input signal and a phase shift. The next question is how to quantify these changes. The answer is to generate a Bode plot, and the easiest way to do this in Simulink is with the LTI viewer.

THE LTI VIEWER

In order to use the LTI viewer, it is necessary to specify an input and output port in the model. This is done in the following manner: Go to the ***Simulink Library Browser* → *Control Systems Toolbox***, drag and drop the ***Input point*** and ***Output point*** icons into the model space. Left-click and drag the ***Input Point*** over the input branch line of the model, release the mouse button, and the point should integrate with the input line (if it does not, a manual connection of the port with other blocks will be necessary). Repeat the process with the Output Point. The model should now look like that in Fig. 4.

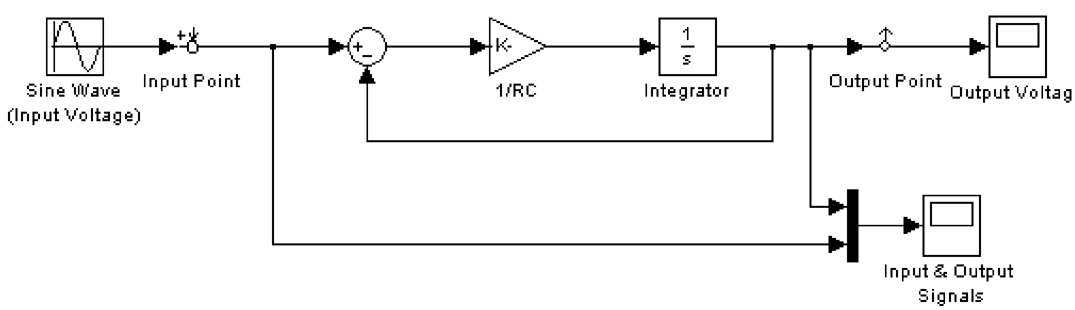

Fig. 4. Model with Input and Output points installed.

Now, to activate the LTI viewer, select ***Tools* → *Linear Analysis***…, and the LTI viewer window will come up. In the menu bar for the LTI viewer select ***Simulink* → *Get Linearized Model***. A plot will appear that shows the response for a step function input for the system (this is the default). For this tutorial, the Bode Magnitude and Phase diagrams are of interest. To get these, right click on the plot and select ***Plot Type* → *Bode***, the LTI viewer display will now look like Fig. 5 below.

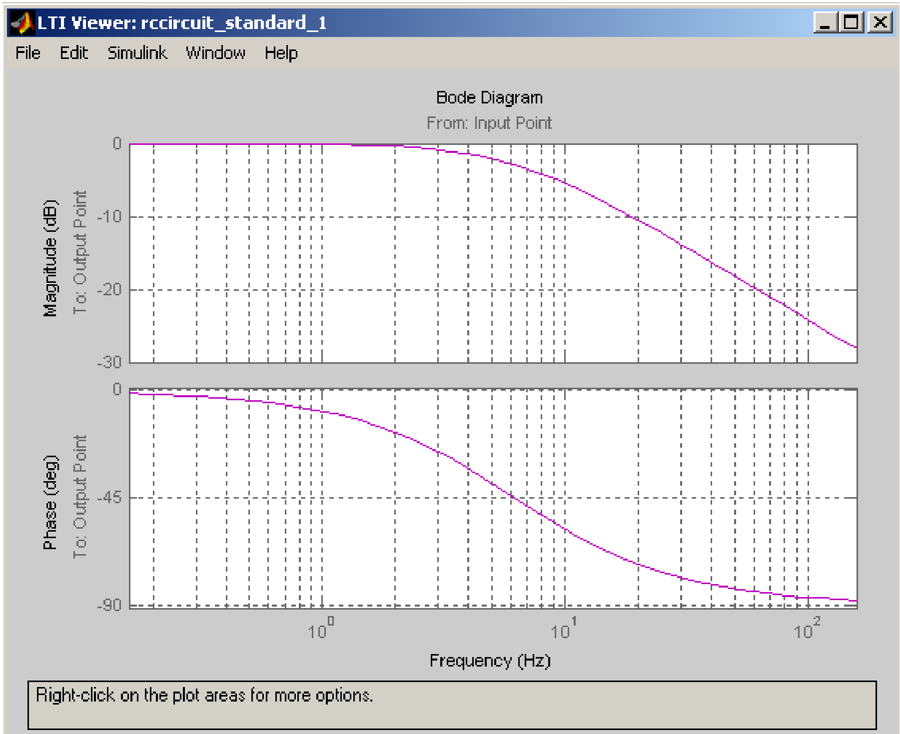

Fig. 5. LTI Viewer with Bode diagram for the model.

To begin interpreting the results, a location of the "Corner" or "Break" Frequency which is the 3 dB down point for the model (i.e. the point at which the input signal is attenuated by 3 dB) will be performed. A quick estimate of this for the circuit can be obtained graphically by extending the slope of the roll-off line in the Magnitude Plot until it intersects the top of the graph as shown in Fig. 6.

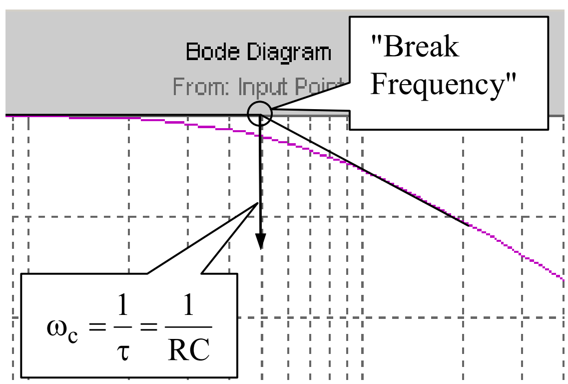

Fig. 6. Graphical method for determining break frequency.

The break frequency can be found by drawing a vertical line from this intersection down to the abscissa. This break frequency is also equal to the inverse of the time constant "τ", which for this example is 1/RC**.**

Using the LTI Viewer, a display of this information can be presented directly. To do this, click on the line in the magnitude plot; a small display box will appear that will display the frequency and magnitude at any point as the cursor is dragged up and down the line. To find the cut-off frequency, find the point where the magnitude attenuation is –3 dB, as shown in Fig. 7.

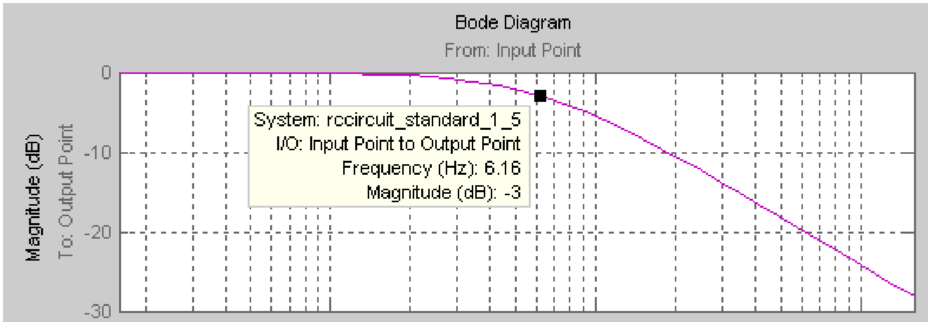

Fig. 7. Display of cutoff frequency for the modeled circuit.

The attenuation of the 3 Hz sine wave input can be found by moving the curser to the 3 Hz point on the plot, as shown in Fig. 8.

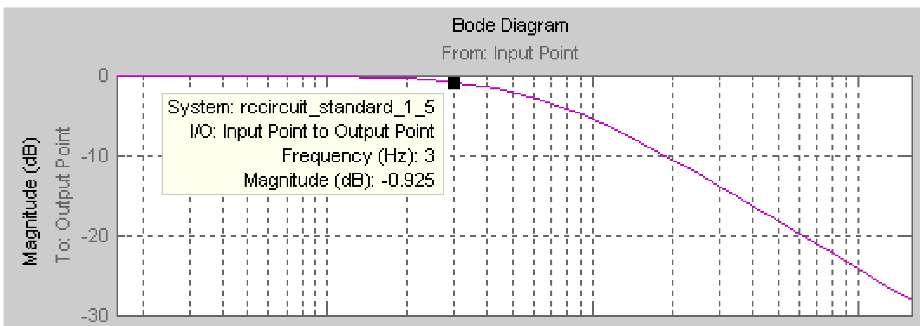

Fig. 8. Attenuation of 3 Hz signal.

From this figure it can be seen that the input signal has been attenuated by -0.925 dB. This can be converted to linear amplitude with:

$$x\{dB\} = 20\log(x)\,, \tag{1}$$

so,

$$x = 10^{\left(\frac{x\{dB\}}{20}\right)} = 10^{\left(\frac{-0.925}{20}\right)} = 0.9\,. \tag{2}$$

In other words, the output sine wave is 0.9 or 90% of the input sine wave. So the usefulness of the Bode diagram for predicting the amplitude distortion of a signal has been proven. However, looking back at Fig. 3, a phase shift is also present. The amount of shift can be quantified by using the lower part of the Bode diagram, which shows the phase shift of the signal, as in Fig. 9.

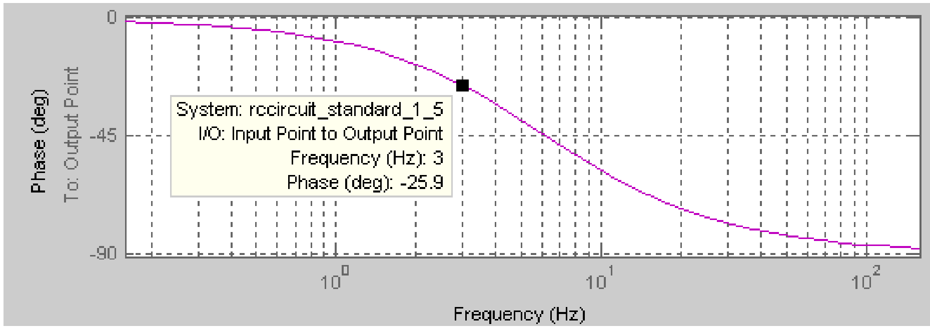

Fig. 9. Phase shift of the 3Hz signal.

From this, it is clear that the output signal "lags" the input signal by 25.9° at 3 Hz (note: the negative sign indicates a phase lag). To check this, a conversion to a time lag, which will allow for a comparison to the time plot, in which the signal is plotted versus time can be performed. In general, this can be accomplished using

$$\Delta t_{lag} = \frac{\text{Phase shift}\,[\text{rad}]}{\text{Signal frequency}\left[\frac{\text{rad}}{\text{sec}}\right]}. \tag{3}$$

Therefore, for this example,

$$\Delta t_{lag} = \frac{(25.9°)\left(\frac{2\pi\,\text{rad}}{360°}\right)}{(3\,\text{Hz})\left(2\pi\frac{\text{rad}/\text{sec}}{\text{Hz}}\right)} = 0.024\,\text{sec}. \tag{4}$$

When this result is compared to the time plot in Fig. 10, it is clear that this is correct.

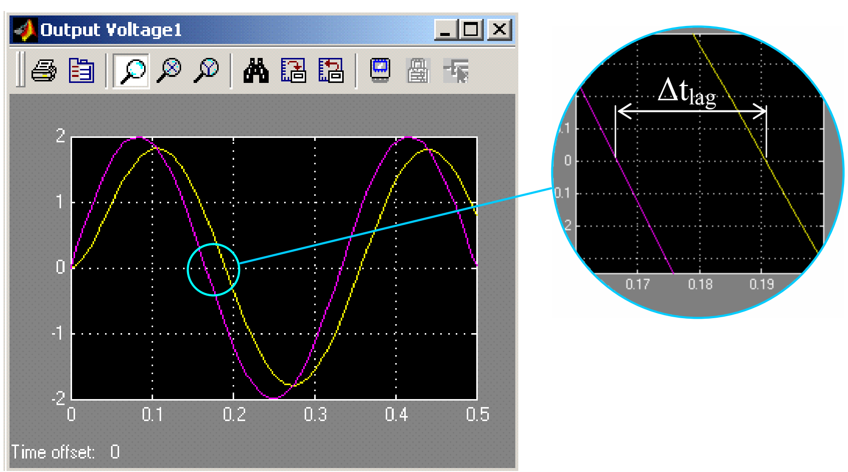

Fig. 10. Time lag of output and input signals.

As seen in this tutorial, the LTI Viewer and the MUX block are powerful tools that can be used to analyze models and quantify the results.