

1 Lab 2: LabVIEW and Control System Building Blocks

1.1 Introduction

Controllers are built from mechanical and electrical building blocks. Mechanical controllers are usually implemented with shafts, gears, pulleys, lever arms etc. Electrical controllers, on the other hand, are subdivided into digital and analog controllers. Digital controllers are implemented with computers and digital circuitry, while analog controllers are implemented with operational amplifiers wired as summers, integrators and differentiators. In this lab, you will implement digital controllers on the computer using LabVIEW.

1.2 Pre-Lab

1. What is the Laplace transform of:
 - An ideal integrator
 - An ideal differentiator
2. Figure 1 shows a plot of $y(t)$. Sketch the derivative of $y(t)$.

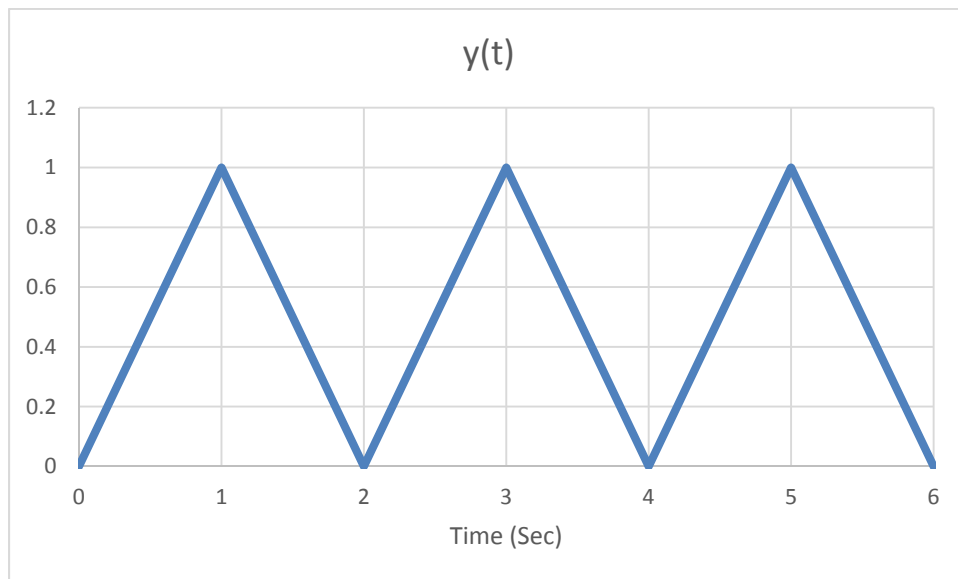


Figure 1 - Plot of $y(t)$

3. Figure 2 shows a plot of $x(t)$. Sketch the integral of $x(t)$.

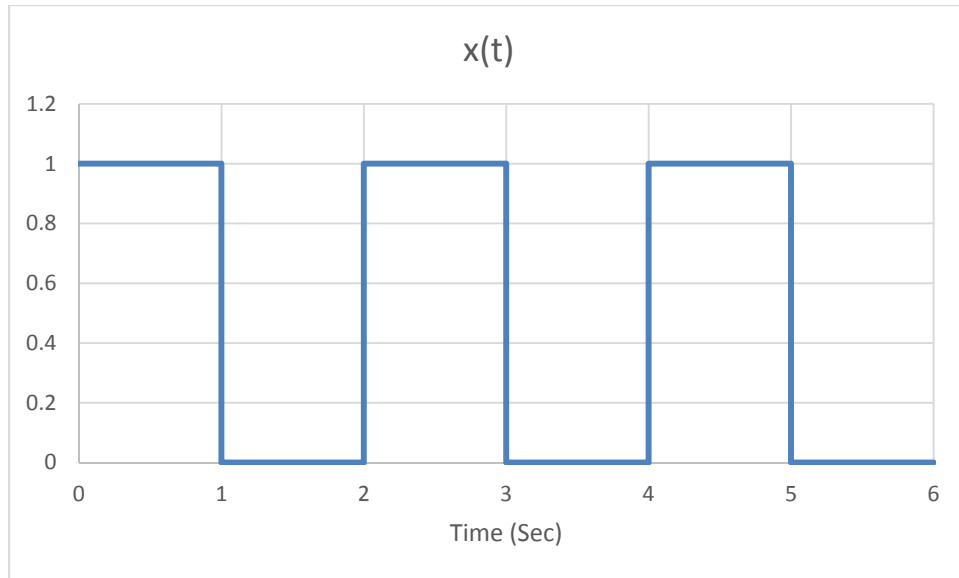


Figure 2 - Plot of x(t)

4. Review tutorials in the "Core LabVIEW Concepts" section of the LabVIEW online tutorials (<http://www.ni.com/getting-started/labview-basics/>)

1.3 Objectives

By the end of this laboratory experiment, you will be able to:

- Build and execute a program in LabVIEW
- Create and plot the control systems building blocks (summer, differentiator, integrator) in LabVIEW

1.4 References

Beyond the exercises in this lab, there are LabVIEW tutorials that you might find helpful: <http://www.ni.com/getting-started/labview-basics/>

Control and Simulation tutorials for LabVIEW: <http://www.ni.com/tutorial/11653/en/>

1.5 LabVIEW

In this section of the lab, you will be introduced to LabVIEW.

Open up LabVIEW 2015 (32-bit) from the desktop icon. If you see the Set Up and Explore screen, click Close. On the LabVIEW screen click Create Project, see Figure 3. Then select the Blank VI template and click Finish. Two windows will pop up, one that looks like graph paper (Front Panel) and one that is a blank white window (Block Diagram). To create programs and simulations in LabVIEW you need to use both

windows. The Front Panel is the interface to set parameters and view data. The Block Diagram is the code behind what creates the Front Panel.

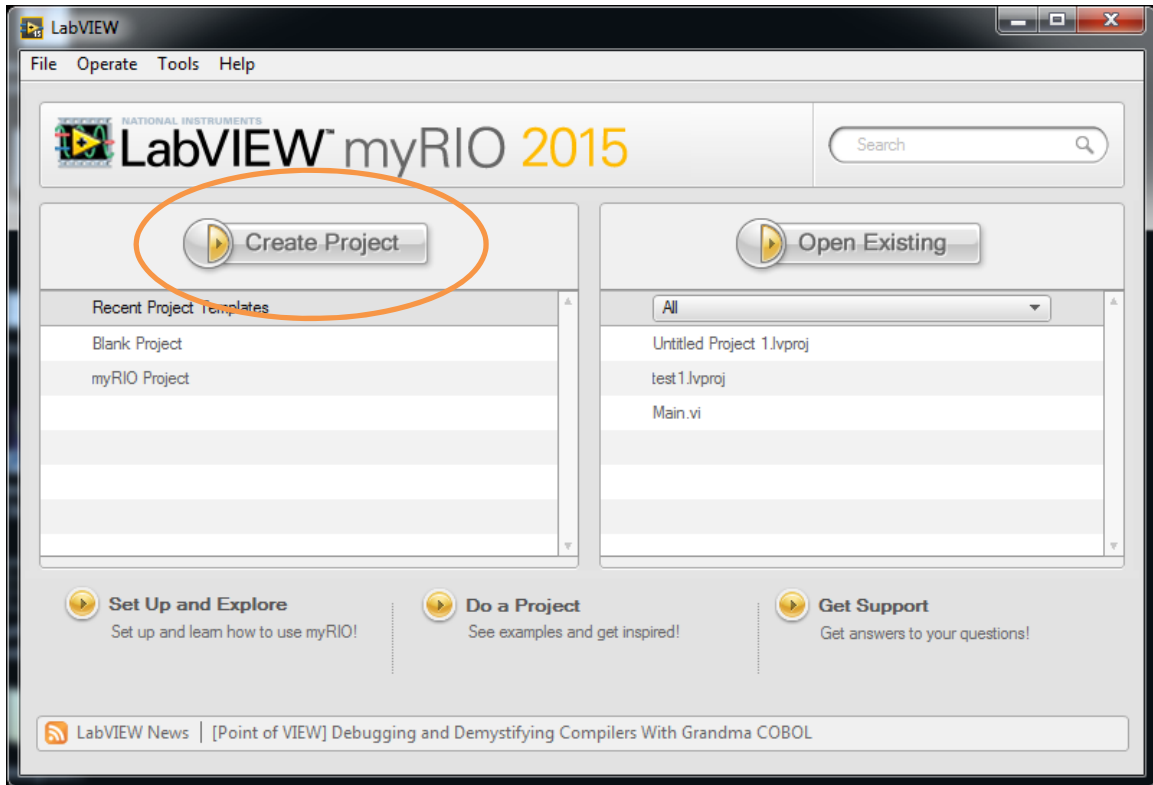


Figure 3 - LabVIEW Screen with Create Project button circled.

1.5.1 Summer

A summing block in simulation takes the sum or difference of the inputs, just like the summation blocks in block diagrams. You will be building the simulation shown in Figure 6 and Figure 7.

- Right click in the Block Diagram window to pull up a list of available functions. Then click the double arrow at the bottom expand the menu. Select Control & Simulation from the menu and click the pushpin icon on the menu that pops out. This will "pin" the menu to your desktop so you can access it more easily. Once it is pinned, it should look like the window in Figure 4.

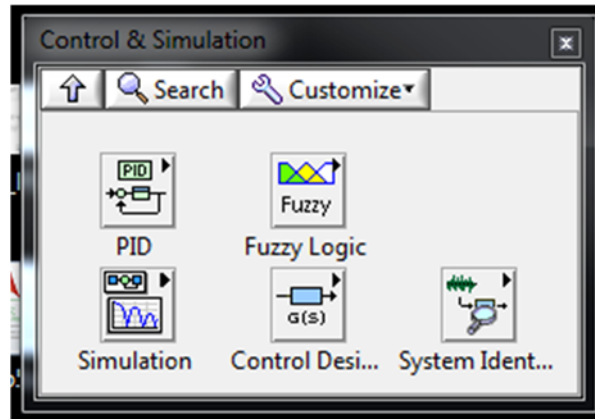


Figure 4 - Pinned Control & Simulation menu

- In the Control & Simulation window, select Simulation to open the Simulation window. In the Simulation window, select Control & Simulation Loop. In the Block Diagram window, click in the upper left corner and drag the cursor to create the Control and Simulation Loop. It should look like an empty version of the dark black box in Figure 7.
- In the Block Diagram window, right click on the block connected to the left of the Control & Simulation Loop and select Properties. Change the following parameters
 - ODE Solver to Runge-Kutta 4.
 - Step Size (s) to 0.01
 - Final Time (s) to 5

Check to make sure the rest of the parameters match Figure 5. Then click OK.

- Now we are going to add the components inside the Control and Simulation Loop to match Figure 7. In the Simulation window, select Graph Utilities. Then click and drag a SimTime Waveform into the Block Diagram window and inside the Control and Simulation Loop. This will add to blocks to the Block Diagram and the Waveform Chart to the Front Panel. You may resize your Waveform Chart in the Front Panel using the double-ended arrow mouse cursor, just like resizing an image in MS Word or Power Point.
- From the Graph Utilities Window, click the Up Arrow button to get back to the Simulation Window. Click Signal Arithmetic. Click and drag a Summation block into the Control & Simulation Loop. To change from subtraction to addition, double click on the Summation block. In the next window, click on the symbol of the port you want to change until it is the operation you want. It cycles through +, -, =, and no input.
- Now go to the Front Panel window. Right click in an empty area of the window. Select Numeric and then Horizontal Pointer Slide. Repeat so you have two different sliders like Figure 6.

- Go back to the Block Diagram and you will have two new blocks corresponding to each of the sliders added in the previous step. Hook each of the sliders up to the summation block and complete the diagram to match Figure 7. To draw wires between blocks hover over the edge of the output of the first block until your cursor changes to a spool of wire, then click on the edge of first block and the port on the input of the block you want to connect it to. Once everything is connected, the arrow in the first button of the tool bar will be connected as it is in each figure. However, if there is a block that is not connected the arrow on the first button will be cut in half.
- To run the simulation, click the first button (arrow) on the tool bar. The result of the simulation will display in the Waveform Chart in the Front Panel window.
- Move the two sliders to new values and run the simulation again. Record your data in the data table. Repeat four more times.

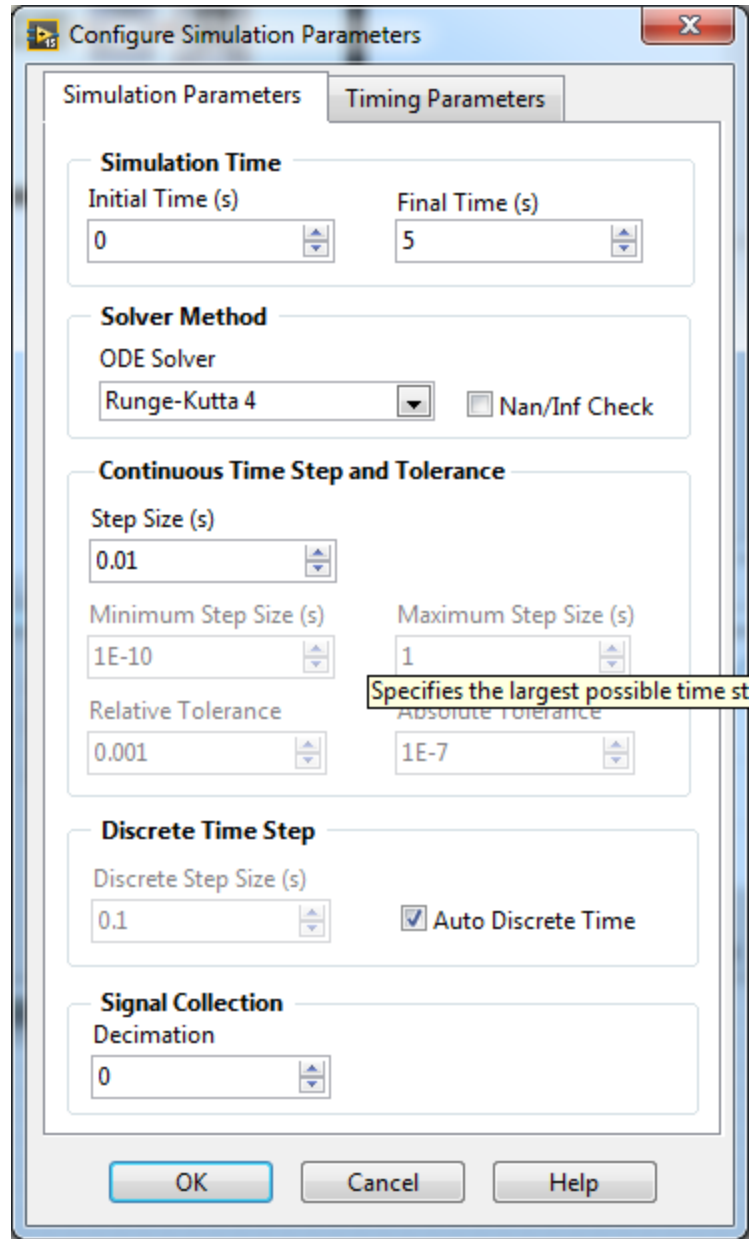


Figure 5 - Parameters window for Control & Simulation loop

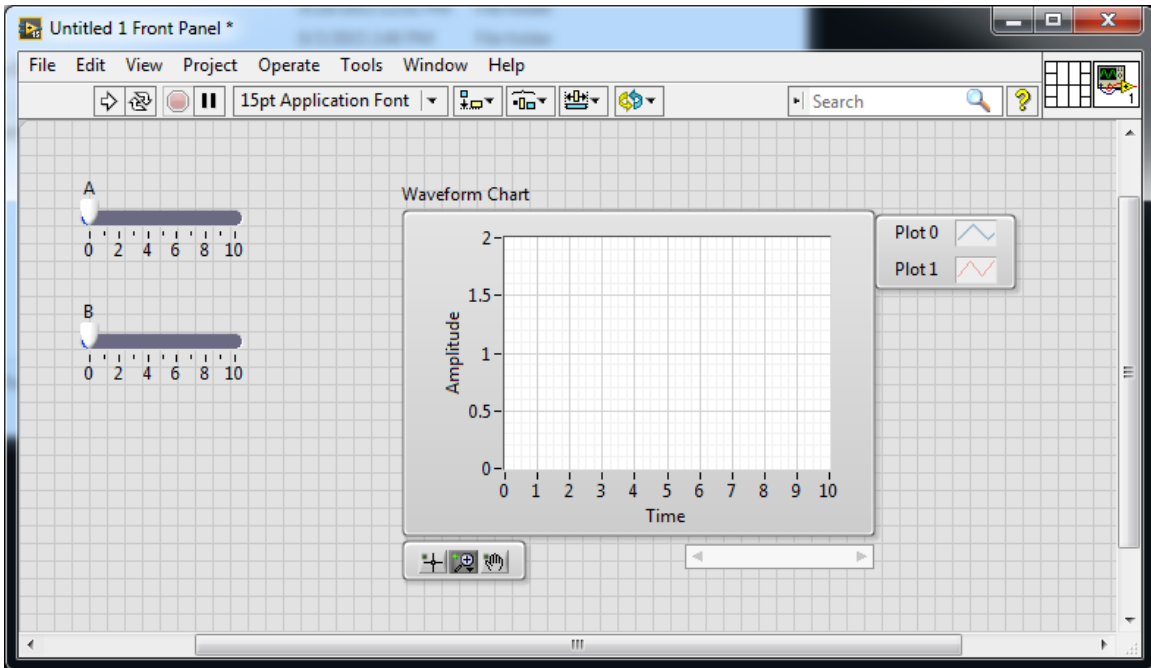


Figure 6 - Front Panel window with the complete summation simulation

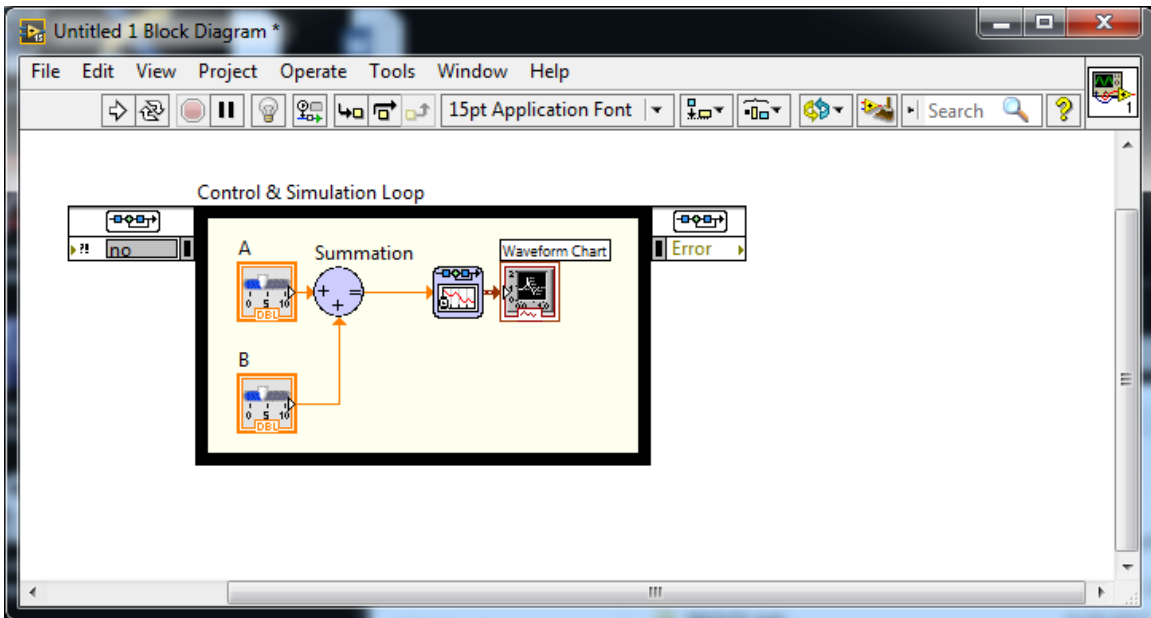


Figure 7 - Block Diagram Window with the complete summation simulation

1.5.2 Differentiator

Next, you will build a simulation of a differentiator. The complete simulation will look like Figure 8 and Figure 9.

- Start in the Block Diagram window from the Summation simulation. Remove the slider inputs and the summation block.
- LabVIEW does not have a Triangle wave generator. However, a triangle wave can be created by multiplying a sawtooth wave and a square wave. The Signal Generator blocks are in Simulation menu of Control & Simulation menu of Figure 4. Drag two Signal Generator blocks in to the Control & Simulation loop.
- Double click on one Signal Generator to set the parameters. Set the following parameters:
 - Signal type to sawtooth
 - Frequency to 0.5 Hz
 - Amplitude to 1.
- Double click on the other Signal Generator to set the parameters. Set the following parameters:
 - Signal type to square
 - Frequency to 0.5 Hz
 - Amplitude to 1
 - Phase to 180 degrees.
- Drag a multiplication block in to the Control & Simulation loop from the Signal Arithmetic menu.
- Right click in the Block Diagram window to pull up the menu. Select Array then drag a Build Array in to the Control & Simulation loop. To increase the size of the Build Array, hover over the center of the bottom edge until you get a double-sided arrow pointing up and down. Click and drag down until it has two rows like Figure 9.
- Select the Simulation from the Control & Simulation menu. Then select the Continuous Linear Systems menu. Drag the Derivative block in to the Control & Simulation loop.
- Connect the blocks as shown in Figure 9.
- Run the simulation and record the results in your data table. The first triangle wave input should look like the one in Figure 8.
- If you would like to zoom in on the graph to get a better reading, right click on the Waveform Chart in the Front Panel window and go to Visible Items. Select Graph Palette.

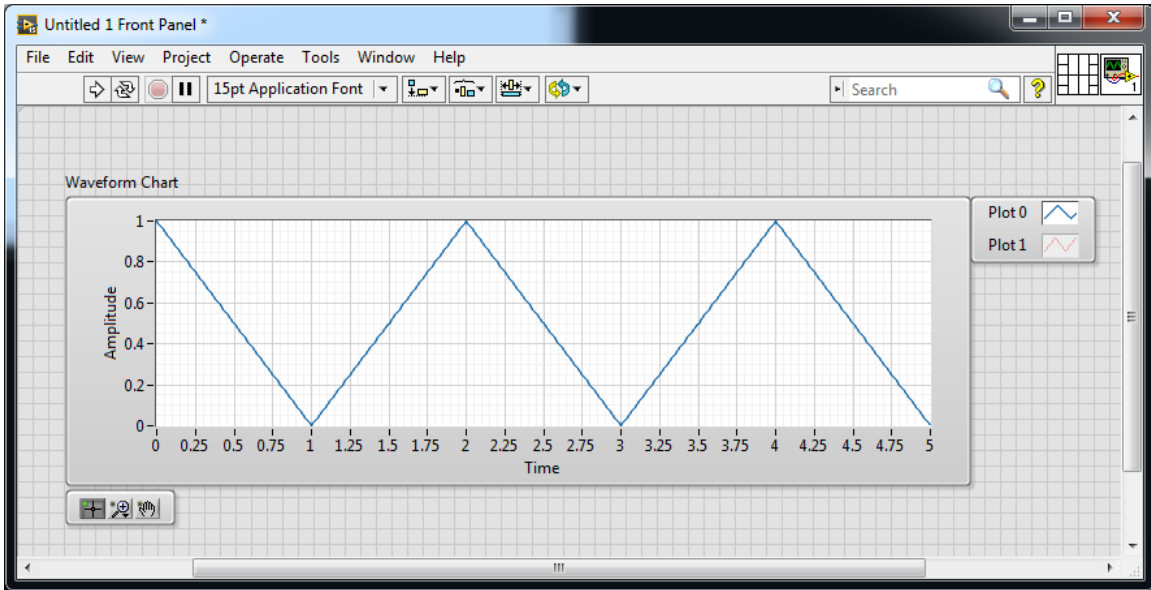


Figure 8 - Front Panel window with the complete differentiator simulation

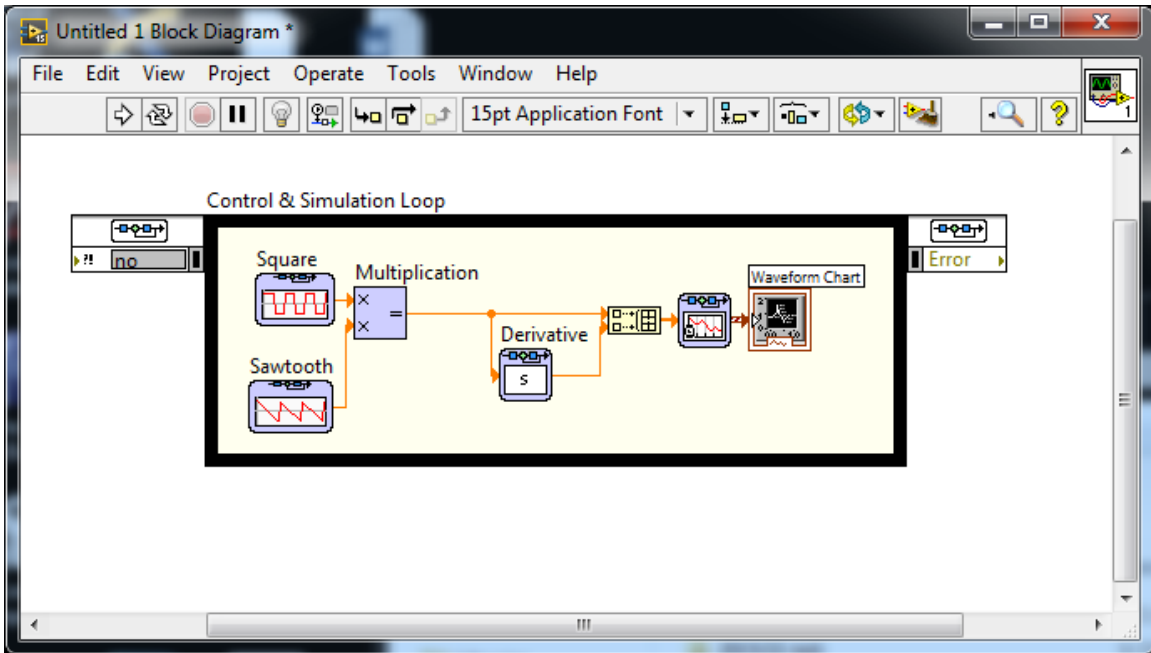


Figure 9 - Block Diagram window with the complete differentiator simulation

- Change the frequency of the square wave and sawtooth wave to match the values in the table below and record the output in your data table

Frequency (Hz) Square & sawtooth waves	Amplitude Sawtooth wave
1	1
2	2
3	3
4	4

- Since we built a differentiator, how would you expect the output amplitude to relate to the input slope? Do you notice any disagreement between the output amplitude and the input slope for a certain input?
- Remove the sawtooth wave and the multiplication block. Then hook the square wave directly up to the derivative block. What happens and why?

1.5.3 Integrator

Finally, you will build a simulation of the integrator. The final simulation will look like Figure 10.

- Start with the differentiator block diagram. Remove the Derivative block and replace it with an Integrator block from the Continuous menu.
- Double click on the square wave and change the frequency to 1 Hz.
- Run the simulation and record your data.
- Repeat the exercise with 4 different amplitudes and record your data.
- Since we built an integrator, how would you expect the output slope to relate to the input amplitude? Do you notice any disagreement between the output slope and the input amplitude for a certain input?

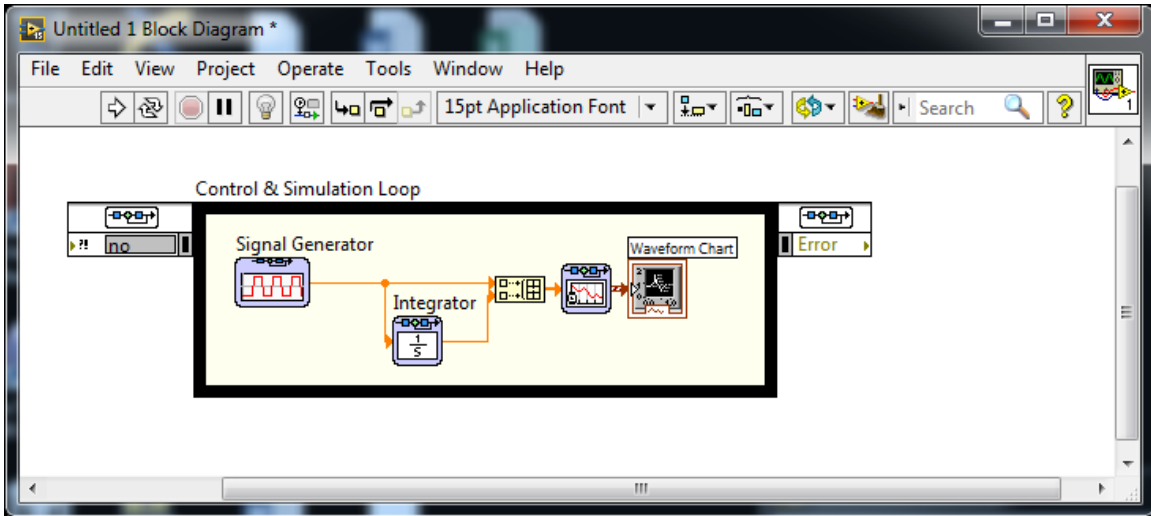


Figure 10 - Block Diagram window with the complete integration simulation

1.6 Post Lab

Include the answers to the following questions in your lab report.

1. Do you think we simulated an ideal differentiator?
2. What happened when you input a square wave (instead of a triangular one) to the differentiator? Why?
3. Considering the transfer functions and the input and output waveforms for the integrator and differentiator, how are the integrator and differentiator related?

1.7 Data sheet

Summing Junction		
Input #1	Input #2	Output

Integrator (Square Wave Input)	
Input Amplitude	Output Slope

Differentiator (Triangular Wave Input)			
Measured Input Frequency	Measured Input Voltage Peak-Peak	Input Slope	Output Amplitude