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Project 2

MCEN 5228-004
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Abstract

In system analysis, engineers study the performance of a system using theoretical and experimental approaches. However, most system do not perform as predicted by the theoretical model. Thus, the need to improve the system performance. In this project, we analyse the performance of and closed loop circuit using MyRio and an RRC circuit by sending a step input of 1 to the system.

Backgrounds

This experiment used an RRC circuit as showed bellow. we were interested in measuring the

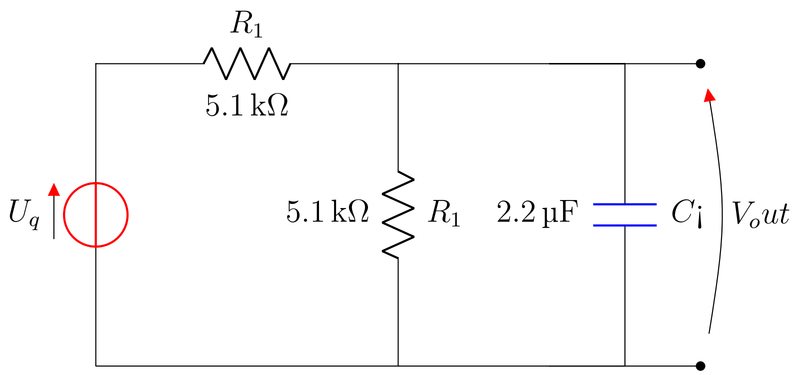


Figure 1: RRC Circuit used during the experiment. The resistors have the same value. The measure voltage is across the capacitor

voltage crossing the capacitor and the resistor in parallel. The measure voltage is compared to the input voltage in oder to analyse the gain of the system, the rise time of, the settle time and others parameters associated the input-output signal. The system was fed with two difference signals:

- A step input signal of 1 volt
- A sinusoidal input of amplitude 1 volt, phase of zero degree and 10 Hzt frequency

Experiment Set-up

Using MyRio, we connected the analog input the pin AI0 and the output to pin AO1. The feedback was completed by subtracting the input signal from output and feeding it to the

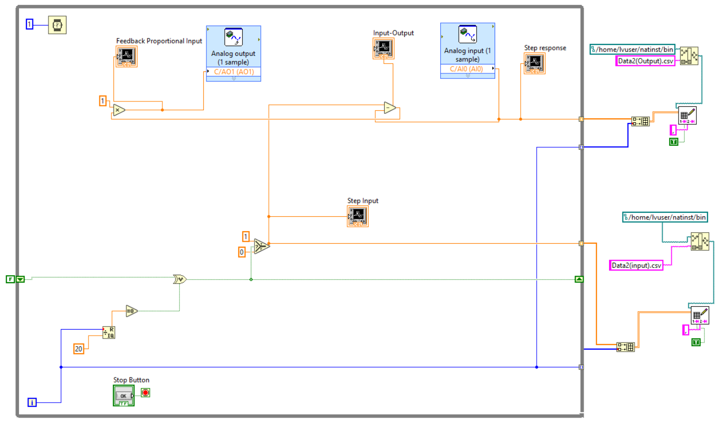


Figure 2: Experimental plot of step input of 1 volt to an RRC circuit.

system as show by the figure bellow.

The MyRio integrated to the circuit is showed bellow. MyRio analog input need a reference voltage to be able to read the correct input data. Thus, we connected the +1 pin to the high voltage coming in the device and the -1 to ground.

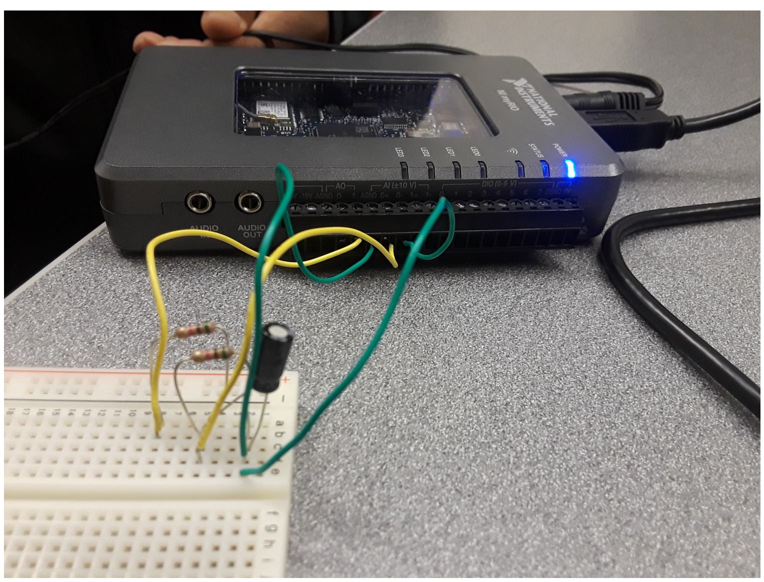
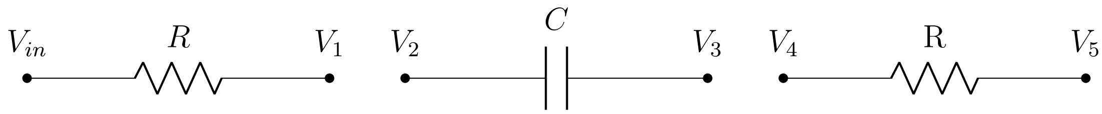


Figure 3: Experimental plot of step input of 1 volt to an RRC circuit.

Theoretical Results

- Idealize Elements



- Derivation of opened loop Transfer Function and Time Domain Equation From the Idealized element, the idealized formula can be derived as follow. 1. $V_{in} - V_1 = R * I$ 2. $V_2 - V_3 = \frac{1}{C} * I_2$ 3. $V_4 - V_5 = R * I$ 4. $V_1 = V_2 = V_4 = V_{out}$ 5. $V_3 = V_5 = 0$ From the above equations:

$$H(s) = \frac{1}{2} * \frac{\frac{2}{RC}}{s + \frac{2}{RC}} \equiv H(s) = \frac{89.13}{s + 178.25} \tag{1}$$

  with R=5.1k Ω and C=2.2 µF The laplace inverse of the equation (1) leads to:

$$y(t) = \frac{1}{2}(1 - e^{\frac{-2t}{CR}}) \tag{2}$$

- Closed loop equation

$$G(s) = \frac{KH(s)}{1 + kH(s)} \tag{3}$$

  with k the proportional controller set to 1 during this experiment

- step input plot
  Using Matlab step function, the plot of the step input is showed below.

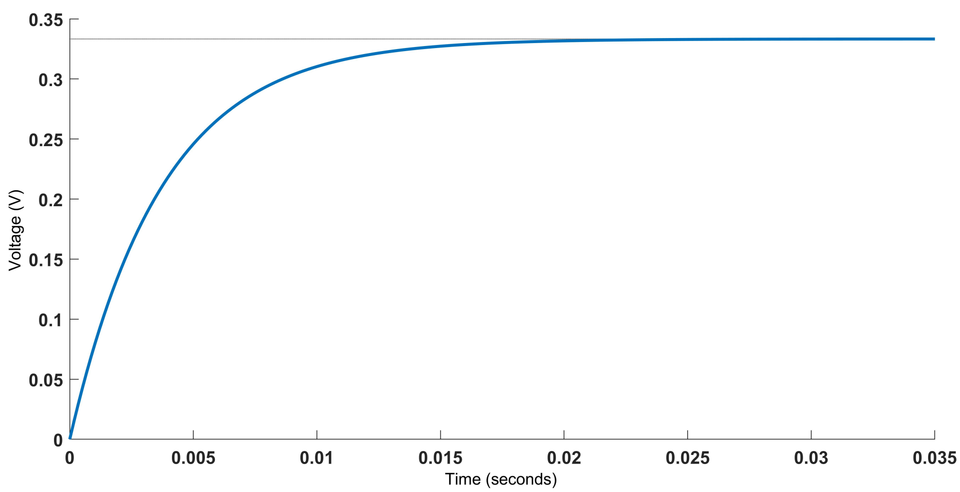


Figure 4: Step input plot of the system using Matlab. The gain of the system is 1/3.

From the plot and Matlab, the gain of the system is 1/3 voltage with a rise time of about 0.0082; a pretty fast response time.

- Bode plot
  The bode plot showed that the system is a low pass filter. The cut off frequency of the

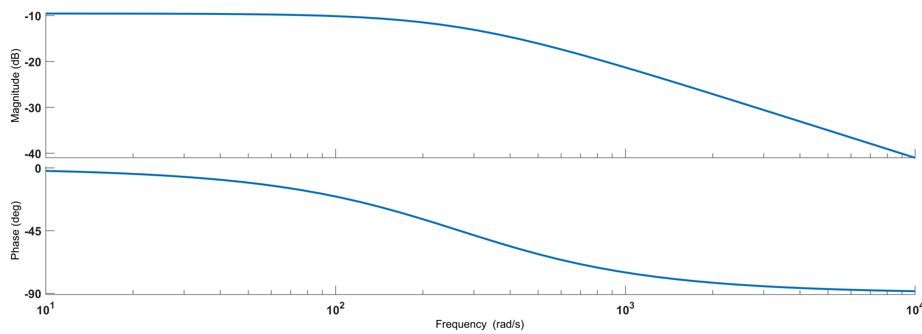


Figure 5: Step input plot of the system using Matlab. The gain of the system is 1/3.

system is Wn=100 rad/s. The system can perform steadily at frequency bellow the cuf of frequency with a constant phase shift of about 90 degrees. From the open loop analysis of the system, it was found that the gain margin and the phase margin of the system are both infinity using Matlab.

- Nyquest Plot

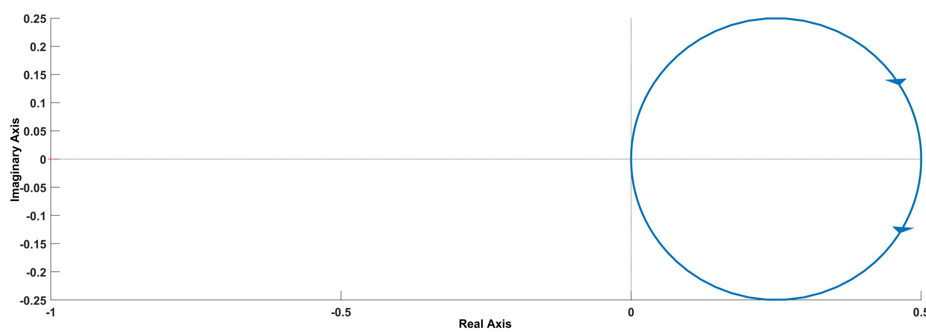


Figure 6: Nyquest plot of the system using Matlab. The data points are far from the instability point -1

From the image above, our system is stable at pole. The system has not zeros. In addition, the system is also robust as -1 is not encircle and any root on the Nyquest plot is far at safe distance from the -1.

- Root Locus
  Below we have the root locus plot of the system

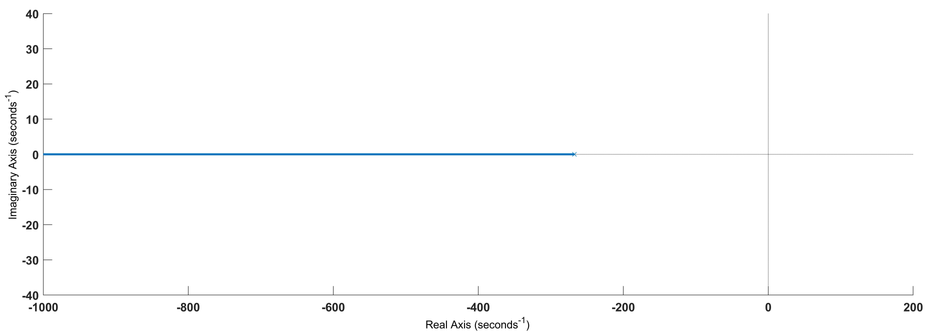


Figure 7: Root locus plot using Matlab.

  From the plot we can deduct that as the value of k increases, the root of the system goes to negative infinity. This confirm the stability of the system as the root can never get into the right half plan of the plot.

Experimental Results

Using MyRio, the system was reproduced experimentally using with LabView as showed in the figure 2. In the diagram, a square wave of the of 50 percent duty circle. This wave was input to the circuit through the analog output of the MyRio. The voltage across the capacitor in the circuit is input to the device from the analog input pin. TO complete the feedback loop, the input to the device is subtracted from the square wave input signal and feed back to the system. The data collected is plotted ans showed in the figure below.

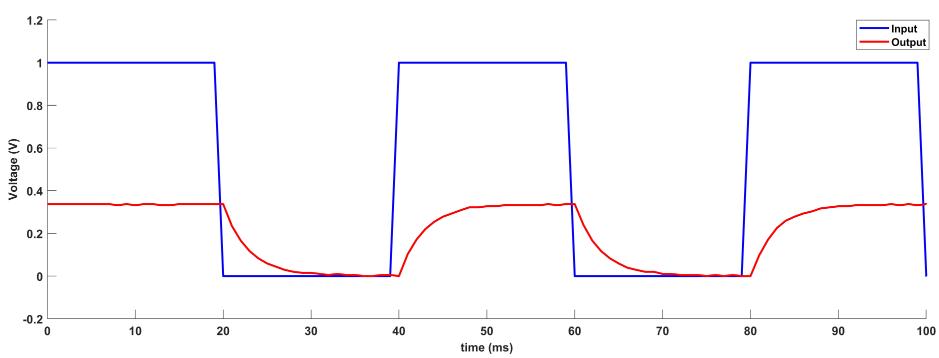


Figure 8: Experimental result of the system using 1 ms sampling rate.

The gain of the experimental system is .334; a percent of error of 0.3 percent that can be neglected and associated tolerance in the value of the resistor and capacitor used in the circuit. The above plot is generated from a loop that ran for every 1 ms. To see effected of how wait time of execution of the loop, Data was recorded at wait time 0f 10 ms and 100 ms. The 10 ms second wait time plot below shows a difference pattern to the 1 ms plot.

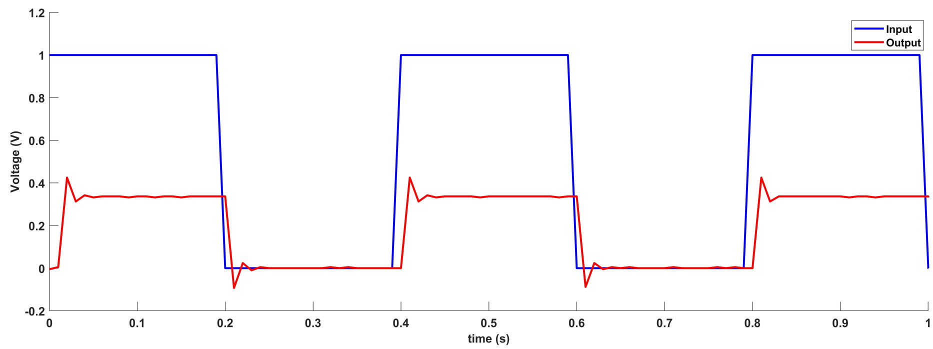


Figure 9: Experimental result of the system using 10 ms sampling rate.

In addition, the plot of the 100 ms below is similar to the the 10ms.

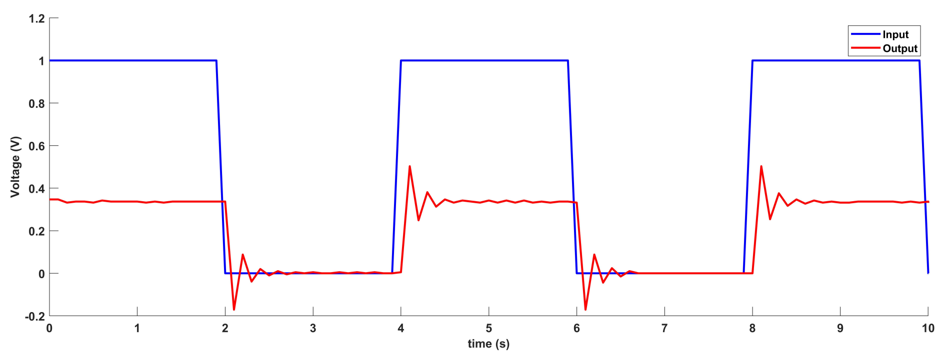


Figure 10: Experimental result of the system using 100 ms sampling rate.

The both have an overshot of 0.1. The inconsistency between the 1 ms, 10 ms and 100 ms could be due to the resoluton of the data point. As we increase the wait time of the loop, the recorded data point a less and therefore has lower resolution on plot.

Conclusion

The experimental and theoretical results in this lab show similarities. We obtained almost the same gain with an error of less than 0.5 percent. It could be concluded that our circuit is reliable on the standard of matching the theoretical result with a proportional controller of k=1 and a sampling period of 1 ms. The difference in the data of the 1 ms and the 10, 100 ms are not explicitly known. We believe it could be due to the change in the sampling frequency with should impact the MyRIo sampling ability.
Our system is robust. The stability of the system can be confirmed from the Nyquest and root locus plot. It was found that, for any value of k, the system will always stay stable. However, the limitation in hardware should be taken into consideration while designing such system
It is important to note that though we have a feedback back loop, our system has gain of 1/3 with an input of 1 volt, which is not desirable because of the huge error. It can be concluded that a proportional controller is not the best fit for this kind of circuit even though a feedback is used when minimizing error is critical.

Matlab Code

```
H_s=tf(89.13,[1,178.3]);
G_f=feedback(H_s,1);
figure(1)
step(G_f)
figure(2)
nyquist(H_s)
figure(3)
rlocus(G_f)
figure(4)
bode(G_f)

clc

%% 10 ms time-lapse
figure(1)
plot(Data2Input10{:,2}*10/1000,Data2Input10{:,1},'b');
hold on
plot(Data2Output10{:,2}*10/1000,Data2Output10{:,1},'r');
xlim([0 100*10/1000]);
ylim([-0.2 1.2]);
xlabel('time (s)');
ylabel('Voltage (V)');
```

```

%% 100 ms time-lapse
figure(2)
plot(Data2Input100{:,2}*100/1000,Data2Input100{:,1},'b');
hold on
plot(Data2Output100{:,2}*100/1000,Data2Output100{:,1},'r');
xlim([0 100*100/1000]);
ylim([-0.2 1.2]);
xlabel('time (s)');
ylabel('Voltage (V)');
```