MECE-606 Systems Modeling Project

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**Lab2: Stability Analysis**

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**ABSTRACT**

The system identification method is primarily used in this lab to obtain the transfer function of the unknown system. The order of the transfer function system is estimated to be 1 or 2. For the second order transfer function, sampling time needs to be fast to see the complete behavior of the rising and falling time. 0 to 5 volts set points are chosen to simulate the system.

**INTRODUCTION**

The black box system data is collected into the National Instrument myDAQ as shown in figure 1.

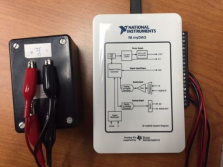


Figure 1. NI myDAQ collecting data from black box

From myDAQ analog channel 0 as the AI0 and analog channel 1 AI1, the output voltage data is measured and obtained. The data are used in system ID to get the transfer function of the system using MatLab system ID toolbox. If the order of the transfer function is unknown, the system ID can still be used but it will be

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more challenging. In fact, the system ID method is used for multiple input multiple output system with unknown transfer function. In this lab, the system order is guessed to be 1 or 2.

The voltage 0 to 5 volts peak to peak are provided to the system while the output is collected.

**ANALYSIS**

From the open loop data, the following first order transfer function is obtained.

, where k is the proportional controller gain.

For the closed loop system, the transfer function equation is

The denominator of the above equation is the characteristic equation of the system. From the characteristic equation, the poles and stability region values of k can be obtained.

When z =0 🡪 k = .419, z=1 🡪k=-1.0557 and z=-1 🡪 k= 1.89367. Stability region bound is between -1.0557 and 1.89367.

The second order system is as the following transfer function.

For the closed loop system, the second order transfer function equation is as following.

Since the time domain is discrete time, by using Jury Stability test, the stability region bound of k values can be determined.

Where . For stability criteria, the basic necessary conditions are F(1) > 0 and F(-1) >0. Furthermore, . For this lab, b value is not required to be found since the transfer function order is 2.

Using the Jury Array, F(1) > 0

For requirement of F(-1) >0

Therefore, K value is between -1.3056 and .6844 for the system to be stable.

**SIMULATION**

The system ID is used to simulate as in figure 2. Real voltage output, real voltage input and the simulation of the first order can be seen in the figure 2. 

Figure 2. The 1st system simulated at 100 Hz with 5 Volts peak to peak

After the transfer function is obtained, the function is simulated with K value of .419.



Figure 3. The simulation of first order transfer function with K value of .419

The input set point voltages 1, 2, 3 and 4 are used as seen in figure 3. For the 1st order system, the simulation of 1st order is similar to the real voltage output. Since myDAQ was not simulated fast enough to get the clear data, 2nd order system simulation isn’t as good as the 1st order system. The simulation with K value of .419 output data are the validation data sets for this lab.



Figure 3. The 2nd order system simulated at 100Hz with 5 Volts peak to peak

The 2nd order transfer function is obtained as in figure 3 using MatLab system ID toolbox. It can be clearly seen that the 2nd order doesn’t fit the voltage output since the time is not sampled fast enough due to the hardware limitation.



Figure 4. The system simulation with .7 K value

The same system is simulate again at .7K value. When K value is big enough, the system starts oscillating. The frequency response time is faster as K value gets bigger.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | 1st sys ID | 2nd sys ID | 1st simulation | 2nd  simulation |
| K=.419 | 0.528 | 0.5658 | 0.0382 | 0.2282 |
| K=0.7 | 0.528 | 0.5658 | 0.0327 | 0.2398 |

Table 1: RMS value for the unknown system simulation

**CONCLUSION**

From the RMS table, it can be clearly seen that the 1st order fits better than 2nd order even though the system is claimed to be 2nd order system. The reason behind it is due to slow sampling time. The controller doesn’t saturate since the voltage supplied is only between 0 to 5 volts. It will saturate if the voltage input is greater than or equal to 10V. The RMS value is not small due to the noise when data are collected. The validation data simulation with K within stability region confirm the transfer function of system ID method is correct. Overall, the lab is completed successfully using Labview, NI myDAQ and MatLab simulation.

clear

clc

close all

filename='Lab2data.xlsx';

filename2='lab2dataVarin1234321kp0419.xlsx';

lab2data=xlsread(filename);

lab2data2=xlsread(filename2);

Data2=[lab2data(:,1),lab2data(:,2),lab2data(:,3)];

Datakp0419=[lab2data2(:,1),lab2data2(:,2),lab2data2(:,3),lab2data2(:,4),lab2data2(:,5)];

k=0.419;

k1=0.419;

t1=Data2(:,1);

t2=Datakp0419(:,1);

y1= Data2(:,2);

y2= Datakp0419(:,2);

u1= Data2(:,3);

u2= Datakp0419(:,3);

sp=Datakp0419(:,5);

Dat =iddata(y1,u1,0.01);

sysTF = arx(Dat,[1 1 1]);

sysTF2O=arx(Dat,[2 2 1]);

tf1=tf(sysTF)

tf12O=tf(sysTF2O)

num=[k\*0.6781];

num1=[0.8954\*k1 0.2766];

den=[1 -.2814+k\*0.6781];

den1=[1 (0.3951+0.8954\*k1) (0.2766\*k1-0.1814)];

sys=tf(num,den,0.1);

sys1=tf(num1,den1,0.1);

ys=lsim(tf1,u1);

ys2O=lsim(tf12O,u1);

ys1=lsim(sys,sp,t2);

ys12O=lsim(sys1,sp,t2);

close all;

figure;

plot(t1,y1,'-b\*',t1,u1,'-.rs',t1,ys,'--g+');

xlabel('Time - Seconds');

ylabel('Voltage - Volts');

grid minor;

legend('Voltage Output','Voltage input','Lsim 1st order');

title('RC Circuit Sampled @ 100 Hz, Lsim 1st Order Approximation');

figure;

plot(t1,y1,'-b\*',t1,u1,'-.rs',t1,ys2O,'--g+');

xlabel('Time - Seconds');

ylabel('Voltage - Volts');

grid minor;

legend('Voltage Output','Voltage input','Lsim 2nd order');

title('RC Circuit Sampled @ 100 Hz, Lsim 2nd Order Approximation');

figure;

plot(t2,sp,'-k',t2,y2,'-b\*',t2,u2,'-.rs',t2,ys1,'--g+',t2,ys12O);

xlabel('Time - Seconds');

ylabel('Voltage - Volts');

grid minor;

legend('Set Point','Voltage Output','Voltage input','Lsim 1st order','Lsim 2nd order');

title('RC Circuit Sampled @ 100 Hz K=0.419');

%first order linear

rms(ys-y1)

%second order

rms( ys2O - y1)

%simulation of output with 1,2,3, and 4 intput voltages p2p

rms(ys1 - y2)

rms(ys12O - y2)