FACULTY OF ENGINEERING, UNIVERSITY OF JAFFNA

EC5030 – CONTROL SYSTEMS

LABORATORY SESSION 4

“DIGITAL CONTROL SYSTEMS”

REGISTRATION NUMBER: 13/E/

AIM: (i) Modelling and analysing sampling system and RC network in MATLAB and Simulink

(ii) Modelling a real Hard Disk Drive (HDD) Voice Coil Motor (VCM) in MATLAB and Simulink. Generate transfer function from Simulink model.

(iii) Tune PI controller for VCM system for emergency retract to fulfil the design requirements

SOFTWARE: MATLAB and Simulink

PART 1 – MODELING AND ANALYSING SAMPLING SYSTEM AND RC NETWORK USING MATLAB SIMULINK

Here, you will be modelling a sampling system and RC network using the in-built blocks available in the Matlab Simulink.

1. Sampling Signals

PROCEDURE:

a) Sine wave signals (Sources Library)

Insert two sine wave signals from Sources library. Change the frequency to 100 Hz and 9900 Hz.

b) Scope (Math Library)

Add a Scope from Sinks library. You may change number of input ports to two to view two signals in two different windows.

I. Connect sine waveforms generators to scope and save the model in the name of “Name_Regno_Lab3_1.mdl”.

II. Run the simulation for 100 ms (set the simulation stop time to 0.1)

III. Display two signals in two windows as shown in Figure 1

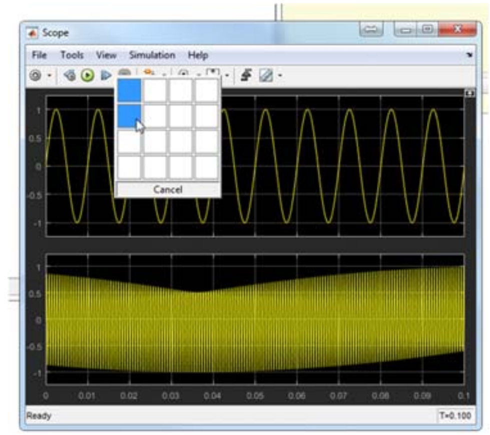

Figure 1: Multiple Input Scope

Note: if any of the signals is not pure sinusoidal (for example in Figure 1, 9900 Hz signal is disordered), change max step size from auto to very small number (1e-6). Model configuration parameter -> max step size

c) Zero-Order Hold (Discrete)

Sampling is modelled by ZOH. Insert two ZOHs and connect the blocks as shown in Figure 2. Change sampling frequency to 10 kHz (Sampling time [0.001 0]) for both ZOHs.

Run the simulation and compare the output of ZOHs with inputs.

Is any output abnormal? This is a real practical issue in digital control system due to the sampling. It is called aliasing effect.

Change 2nd source frequency to 10100 Hz, 6000 Hz, 5000 Hz and 4000 Hz. Compare the output for your further understanding.

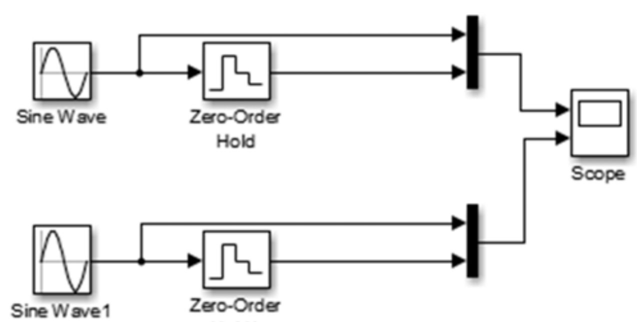

Figure 2: Sampling Signals Using Zero-Order Hold

2. RC network

PROCEDURE:

a) Derive the transfer function for bellow RC network in R, C1 and C2.

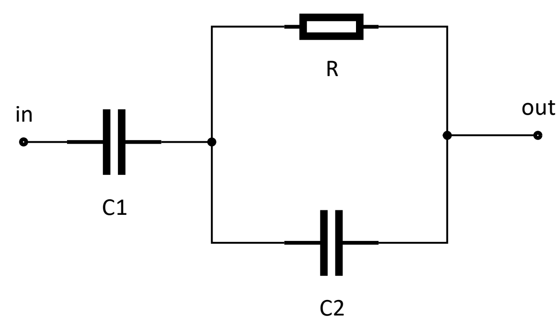

Figure 3: RC Network

b) RC network in Simulink

Add a transfer function block, write derived transfer function in terms of R, C1 and C2 and write a Matlab script to set R = 52kΩ, C1 = 560 pF and C2 = 6pF. Plot the output waveform for step input. Save the model in the name of "Name_Regno_Lab3_2.mdl" and matlab script as "Name_Regno_Lab3_2.m".

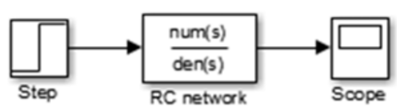

Figure 4: RC network Simulink Model

PART 2 – MODELLING A REAL HARD DISK DRIVE (HDD) VOICE COIL MOTOR (VCM) IN MATLAB AND SIMULINK.

The HDDs contain rotating magnetic media and read/write heads. Heads position is controlled by VCM current. During read or write operation heads positions are precisely sensed signals from magnetic media. During power saving mode heads velocity is sensed by VCM bemf. In this practice student will focus only on power saving mode.

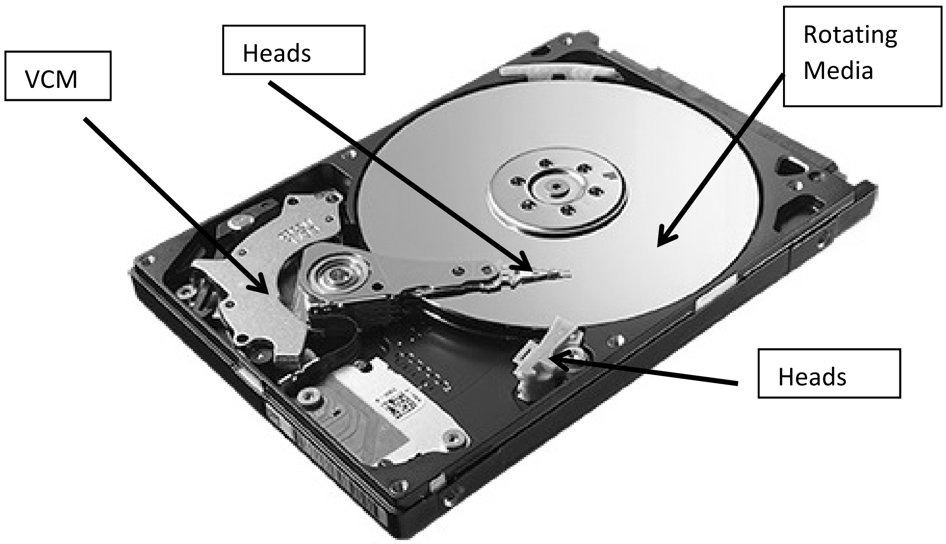

Figure 5: HDD's Components

VCM driver circuit contains four op-amps and 1o resisters and it is bit complex to drive transfer function. With the basic power electrons knowledge, students should be able to develop similar models. However it will take time, therefore Simulink model is given to students.

Current through VCM is controlled by DAC as shown in Figure 6. Part2.mdl is the Simulink file and Part2Init.m is the Matlab file to initialise the parameters.

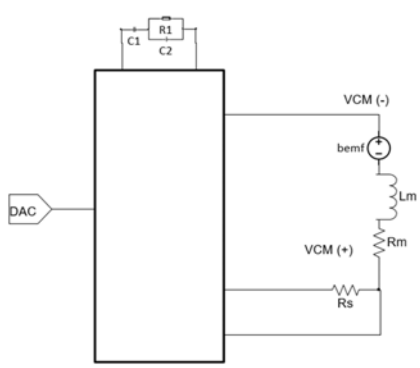

Figure 6: VCM and Driver

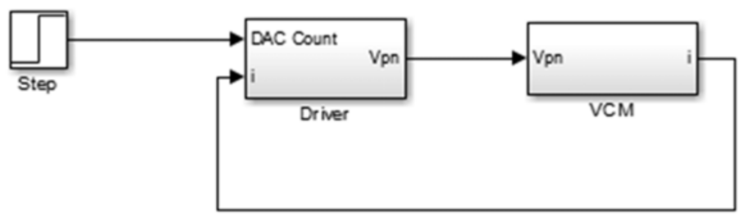

Figure 7: VCM and Driver Simulink Model

PROCEDURE:

a) Run the Simulink with given values. Add a scope to monitor VCM current. Change the filenames to “Name_Regno_Lab3_2”.

b) Extracting a linear model into Matlab:
   1. Connect a input port and output port as shown in **Figure 8**
   2. To extract continuous-time linear state-space model from Simulink run
      ```
      >> [A,B,C,D]=linmod(' Name_Regno_Lab3_2')
      ```
   3. To convert state-space representation to transfer function run
      ```
      >> [num,den]=ss2tf(A,B,C,D)
      ```
   4. To create transfer function run
      ```
      >> sys = tf(num,den)
      ```
   5. To get step response.
      ```
      >> t = 0:10e-9:10e-4; % time resolution and duration
      are same as Simulink model
      >> step(sys,t)
      ```
   6. Compare the result with part a

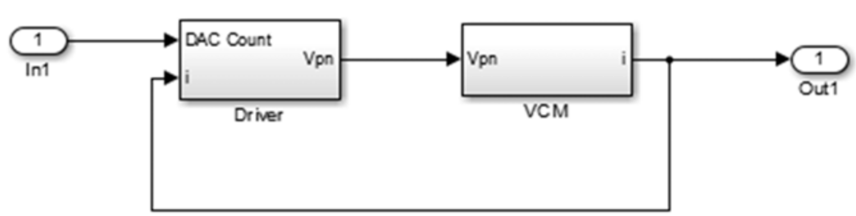

Figure 8: Extracting Model from Simulation

PART 3 – TUNE PI CONTROLLER FOR VCM SYSTEM FOR EMERGENCY

Heads are retracted from media to ramp upon power loss or emergency cases like falling laptops.

Retract system is more complex than in part2. This system included friction, magnetic latch force and air dragging force. To develop this level of simulation students need to have fundamentals of mechanical, aero dynamics and power electronics knowledge. As this lab is to develop experience in digital control Simulink model is developed for students. Part3.mdl is the Simulink file and Part3Init.m is the Matlab file to initialise the parameters.

Drive circuits is different from part 2 as when power is lost different controller is used, which consumes much less power than normal controller.

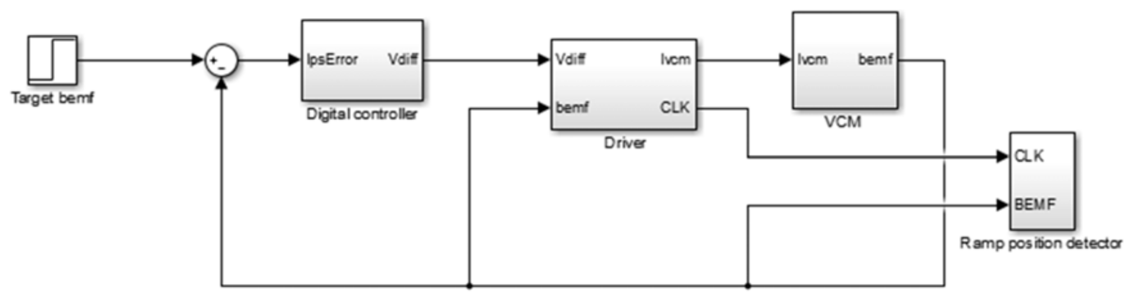

Figure 9: Retract Simulink Model

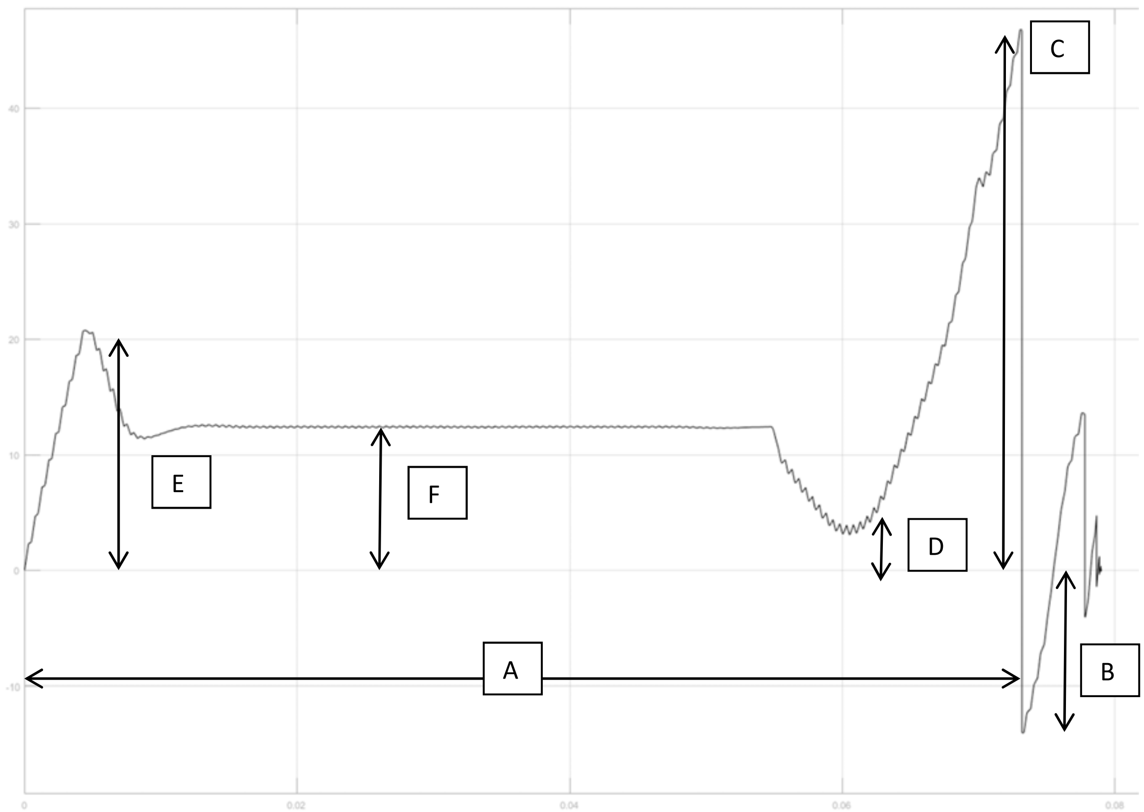

Figure 10: Velocity profile

Design requirements

1. Heads should reach within 75 ms (A < 75)
2. Ramp hitting velocity should be less than 50 inch per second (C < 50)
3. Bouncing back velocity should be -15 inch per second (B > -15)
4. Minimum traveling velocity should be more than 3 inch per second (D > 4)
5. Overshoot should be less than twice of target speed (E < 2* F)

PROCEDURE:

Recommended initial settings are given in part3Init.m files. Student may start with these setting and fine tune the values of `TargetBemf, PI_Gain, I_Gain, Toff and DutyRatio.` There are limited selections given to simply the problem

a) Tune `TargetBemf` such that A is almost less than 75 ms. Recommended starting value is 0.12
b) Tune `PI_Gain & I_Gain` to satisfy overshoot, maximum and minimum velocity
c) Tune `Toff & DutyRatio` to have smother velocity profile
d) Fine tune all parameters.