ELEC 3004 / 7312 – Digital Linear Systems: Signals & Controls **2014**

Problem Set 3: Filters

Total marks: 80 **Due Date:** Monday, May 12, 2014 (at 11:59pm, AEST)

Note: This assignment is worth **15%** of the final course mark. Please submit answers via Platypus. It is requested that solutions, including equations, should be typed please. The final grade is the median of the marks from the peer reviews and the staff (with provisions for review). Finally, the tutors will ***not*** assist you further unless there is real evidence you have attempted the questions. Thank you very much. :--)

Short Questions

(Please keep it simple)

Q1. Discrete Transfer Functions **[5 points]**

Find discrete transfer functions for the following difference equations. What kind of filter does each transfer function represent?

1. $y[n]+22y[n-12]=12x[n-2]-16x[n-9]$
2. $y[n]=x[n-9]+16x[n]$

Q2. Calculus: You Can't Beat Discrete **[5 points]**

Briefly derive the transfer functions for both the:

1. Digital integrator; and
2. Digital differentiator.

Do your transfer functions uphold the fundamental theorem of calculus? Do you think derivatives and integrals are simpler in continuous or discrete time?

Q3. Derivative Stability **[10 points]**

In MATLAB, generate a 50-vector of white Gaussian noise: `noise = wgn(1, 50, 1)`. Run the noise through a 1kHz digital differentiator (hint: see Q3).

1. Now using this FIR filter[1], can you make the differentiator more stable? Present before and after plots to demonstrate the difference.
   Hint: `load('LPF.mat');` then use the `filter(...);` command to apply the filter.

2. Please discuss what the filter is doing. What type of filter is this?

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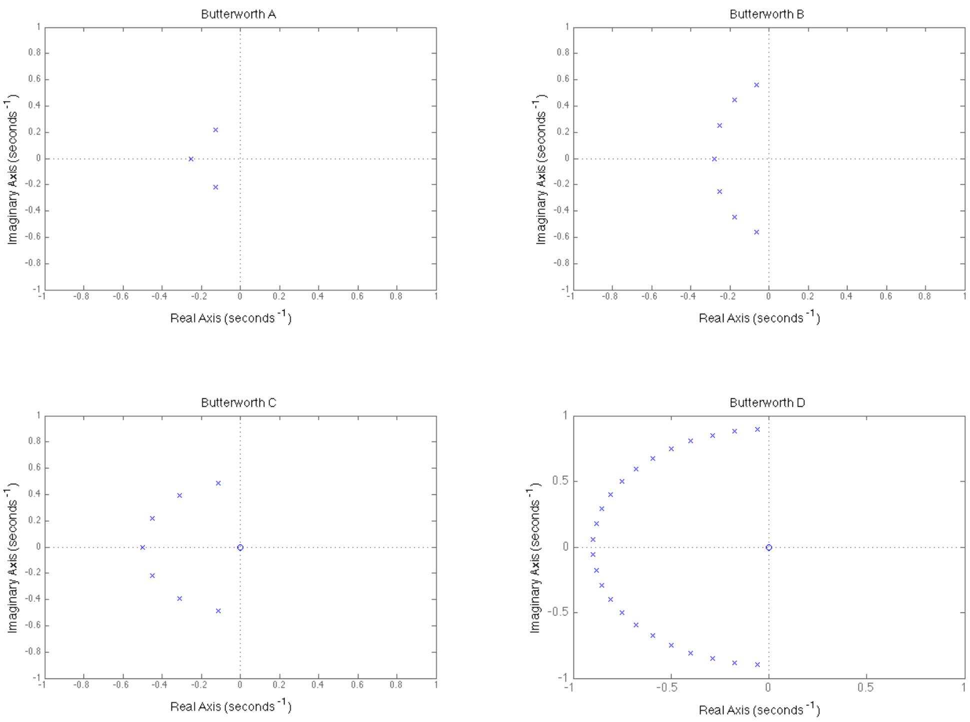
[1] http://robotics.itee.uq.edu.au/~elec3004/assignments/PS3_Q3_LPF.mat

Q4. For What It's Butterworth **[15 points]**

You are given the following [pole-zero maps](http://robotics.itee.uq.edu.au/~elec3004/assignments/PS3_Q4_butters.png)[2] for four analog Butterworth filters A, B, C and D.



Answer the following questions about these plots. You are encouraged to experiment with MATLAB.

1. Which filter has the highest order?
2. Approximately what are the cutoff frequencies of each filter?
3. Which filters are low pass and which are high pass? Could any of them be bandpass?
4. Something seems odd about one of the Butterworth filters. Which filter is the odd one out? How might its unusual shape affect its performance?

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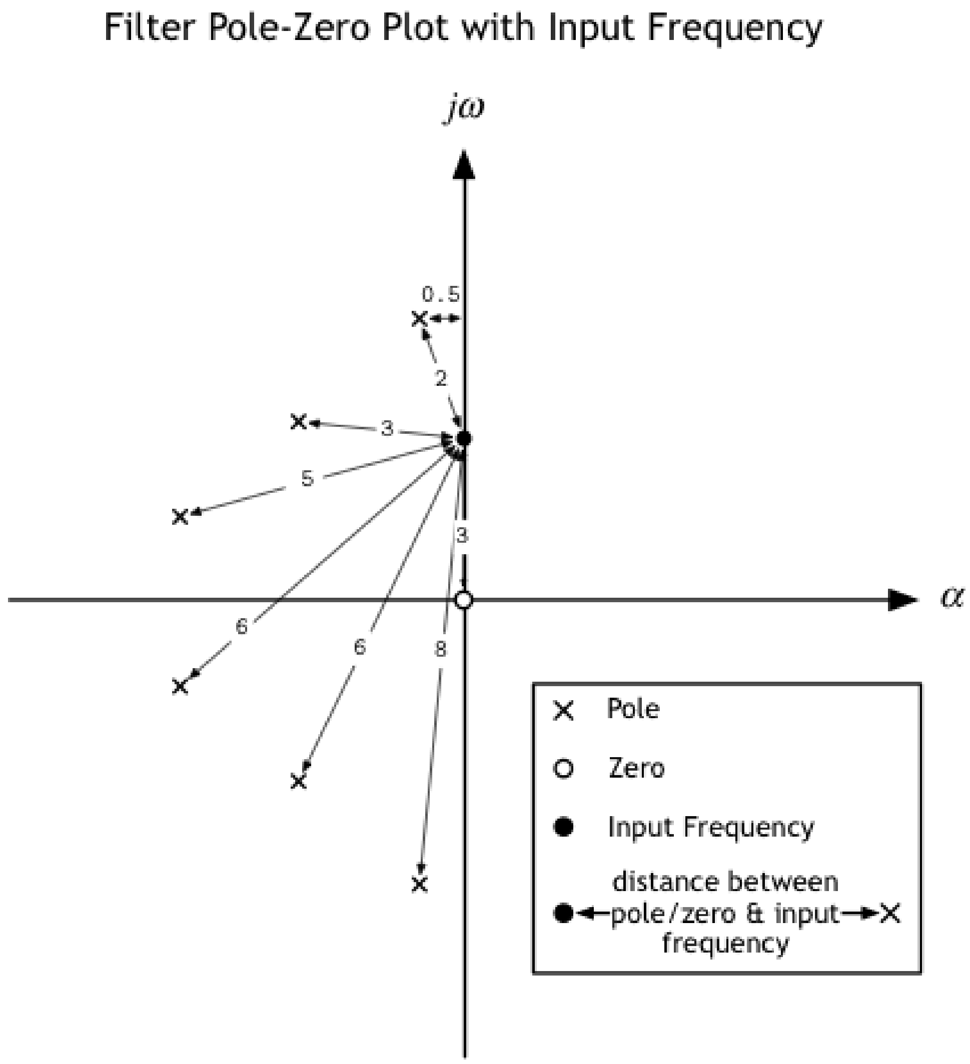
[2] http://robotics.itee.uq.edu.au/~elec3004/assignments/PS3_Q4_butters.png

Q5. Easy PZ **[15 points]**

Consider the following plot.



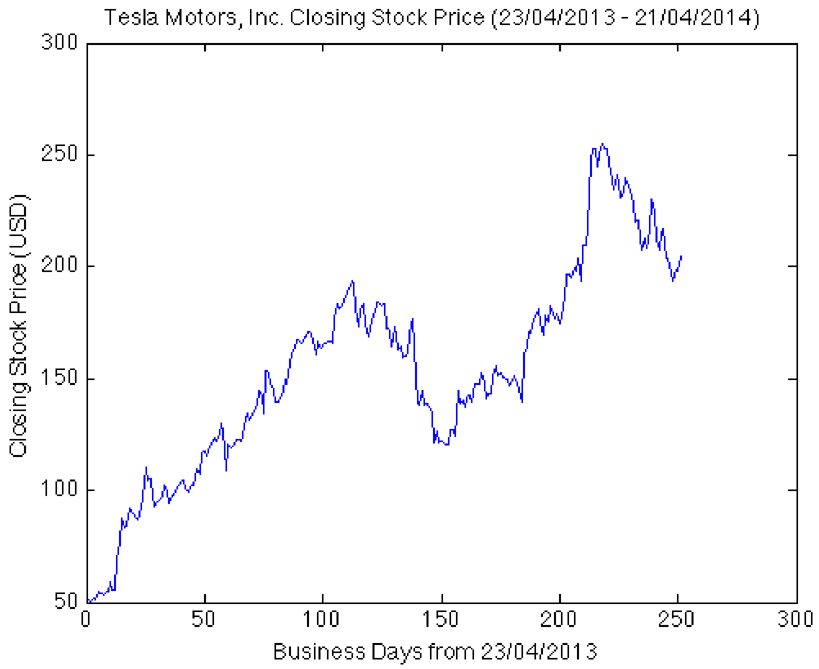
Derive the following details about the filter represented by this pole-zero plot.

1. DC Gain
2. Input Frequency Gain (assume a constant factor of 10^4 in the transfer function numerator)
3. Cutoff frequency

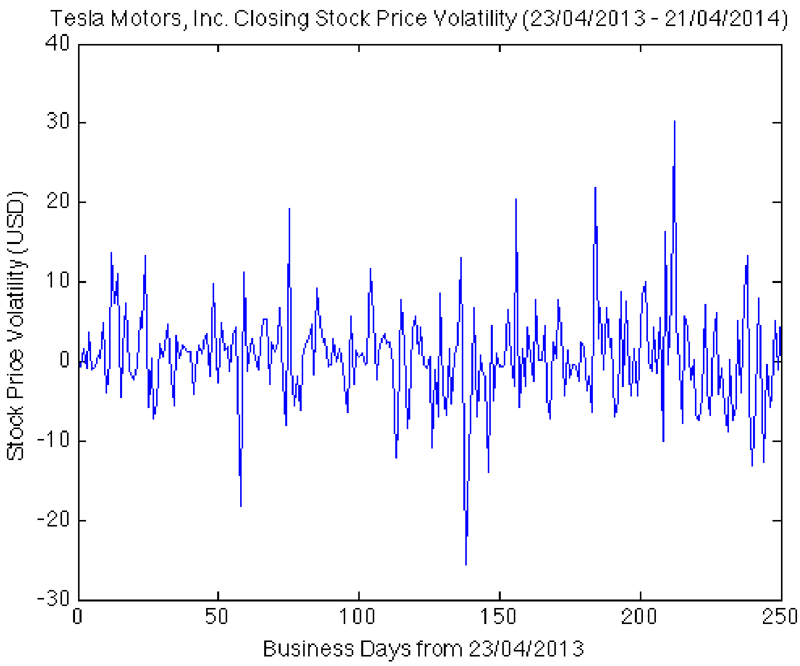
4. **Extra Credit:** Can the Input Frequency Phase be determined? If so, what is it? If not, why?

Q6. Filters: What More Could You Quant? [30 points]

Day trader Nick Leeson is researching Tesla Motors, Inc[3]. He wants to predict a trend using Tesla's closing stock prices from 23/04/2014 to 21/04/2014.



Nick takes the derivative to quantitatively assess the current trend of Tesla's closing stock price.



However, he finds the derivative is too volatile to be useful. Nick has contracted you to clean this data. He has provided the prices in a matlab data file[4] for you.

[3] https://www.google.com/finance?q=tesla
[4] http://robotics.itee.uq.edu.au/~elec3004/assignments/PS3_Q6_tslaClosingPrice.mat

Part I: Let's Get Moving:
A Simple Moving Average (SMA) Filter

Write a MATLAB program to do the following to clean the data with a moving average filter:

1. Develop a difference equation for a causal, five-day simple moving average filter.
2. Calculate the filter's z-domain transfer function.
3. Realise the system (make a block diagram) using delay (z^{-1}) elements.
4. Using any method you like, calculate and plot the new, five-day averaged data set and its discrete derivative.

Discuss the approach of averaging before analysis. Specifically:

1. Is this approach analogous to any traditional methods in electrical engineering?
2. Is a moving average filter like a low-, high- or bandpass filter? Or is it something entirely different?

Part II. Let's Get Exponentially Rich:
An Exponential Moving Average (EMA) Filter

After contemplating the nature of the stock market, you decide to change the filter. You think that older prices are less relevant to the current trend. You decide to exponentially lower the weight of older terms in the average.

You may use the following difference equation.

$$m[n] = \alpha \cdot p[n-1] + (1-\alpha) \cdot m[n-1]$$

$$m[n] = \text{exp moving average on day n}$$

$$p[n] = \text{closing stock price on day n}$$

Follow steps 2, 3 and 4 (of Q7) again, tuning α as you see fit.

Discuss the new results. Specifically:

1. Have the results actually changed?
2. What is the effect of alpha?
3. Is it possible to implement an FIR EMA filter?
4. If you could implement an FIR EMA filter, would you? Why or why not?