MTH 321 Final Report

John Behman

December 11, 2019

1 Introduction

For my final project I use MatLab [1] to develop signal filters. My major is electrical engineering, and an important field within electrical engineering is signal processing. Engineers work to design filters for their systems. These filters can be designed to filter out designated frequencies from the output. For example, a system could have multiple inputs, but only want to produce output signals within a given frequency threshold,. A filter can be used to filter out other frequencies therefore only passing through signals with the desired frequency.

Figure 1 describes how these filters can be designed:

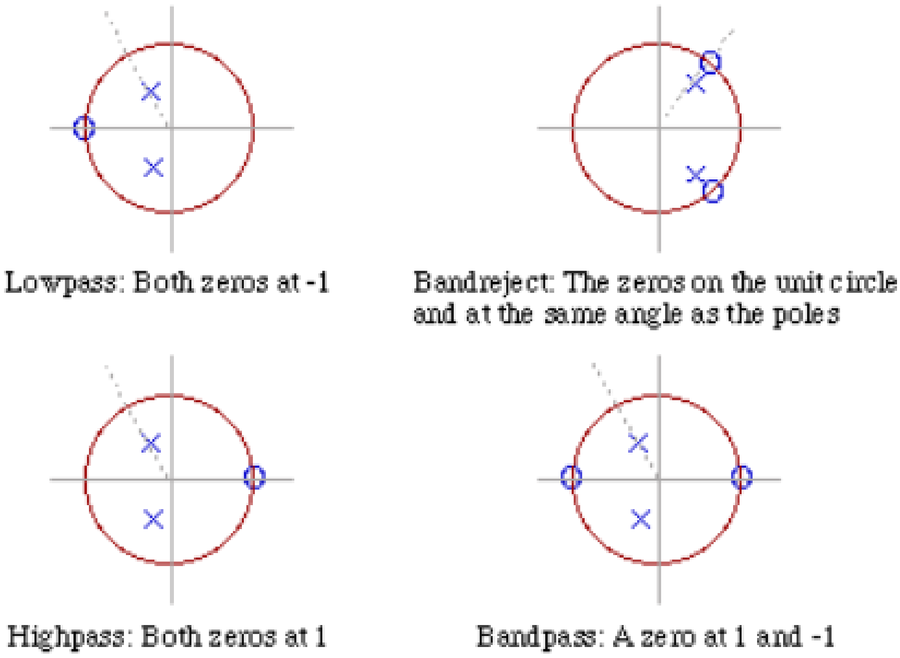

Figure 1: Pole Zero Graphing Explanation [2]

This graph explains how different filters are designed. A low pass filter will pass through signals with lower frequencies. Band pass filters pass through signals with frequencies in the middle. A high pass filter will pass through high frequency signals. This response is created by applying the rules seen above. The placement of poles in relation to the placement of zeros will result in varied frequency response of the filter that is produced. This filter can then be development in physical hardware by electrical engineers by using the pole zero placement to develop a physical system that meets the parameters.

2 Code Explanation

Figure 2 shows the code I developed for the project.

```matlab
t=-1:.01:1;
r=sqrt(1-t.^2); %bottom circle on graph
r2=-sqrt(1-t.^2); %top circle on graph
plot(t,r)        % plot the first circle
hold on
grid on
plot(t,r2)       % plot the second circle
axis([-1.5 1.5 -1.5 1.5])
title('Insert the poles')
[xp,yp]=ginput;      % take user input on the unit circle graph
for k=1:length(xp)
    if yp(k)~=0
       %calculate the conjugate of the location clicked by the user
       xp(length(yp)+1)=xp(k);
       yp(length(yp)+1)=-yp(k);
    end
end
plot(xp,yp,'x')      % plot the poles on the graph
title('Insert the zeros')
[xz,yz]=ginput;      % take user input on the unit circle graph
for k=1:length(xz)
    if yz(k)~=0
        %calculate the conjugate of the location clicked by the user
       xz(length(yz)+1)=xz(k);
       yz(length(yz)+1)=-yz(k);
    end
end
plot(xz,yz,'o')      % plot the zeros on the graph
zr=xz+i.*yz;      % place zeros in vector
pl=xp+i.*yp;      % place poles in vector


H=zpk(zr,pl,1,-1);     % create zero pole gain model with zpk
hold off
%graph the magnitude and frequency response of the designed system
figure
options=bodeoptions;
options.grid = 'on';
%options.freqscale = 'linear';
options.magscale= 'linear';
options.magunits = 'abs';
bode(H,options)
```

Figure 2: Source Code

The MatLab program produces an empty pole zero plot with a unit circle for reference. The user is then able to provide input via the mouse to select the location of poles on the graph. Each pole selected on the graph receives the conjugate pole as well on the graph. After selecting as many poles as the user would like, they can click enter to indicate all the poles selected. The user then does the same process for entering holes onto the plot. After completed, the user can hit enter and the frequency response is produced. The graph indicates the frequency and phase response of the system produced. This information shows what type of filter was produced, indicating the frequencies at which signals will pass through the filter. The user can then save the outputs and run the program again to produce a new filter with new parameters.

3 Code Interaction and Outputs

In this section, I will walk through the procedures above, providing graphs to indicate what appears at each stage of the user input interaction. After running, the user is provided the user input graph in figure 3. It can be seen that there is a cursor indicating where the user is hovering.

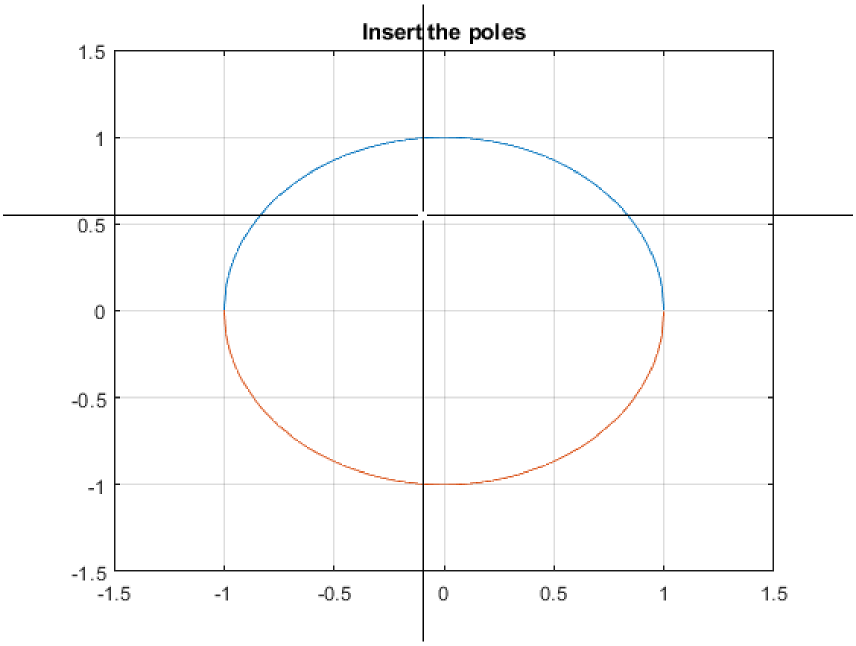

Figure 3: Empty Graph for User Input

Following this, the user will enter their pole input producing a graph such as figure 4.

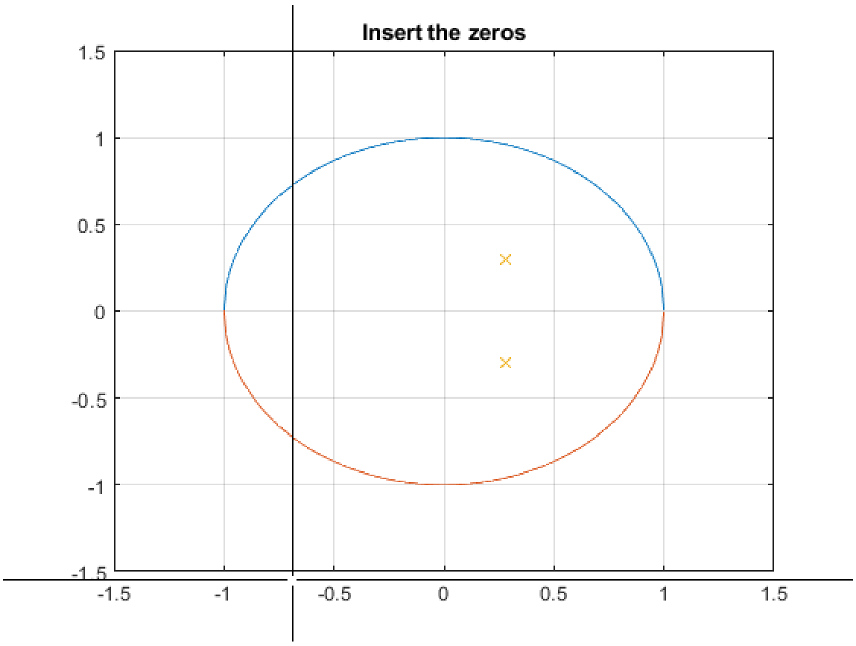

Figure 4: User Designated Poles Placed on Pole Zero Graph

The same process is repeated for entering the zeros of the system. After hitting enter the pole zero graph and frequency response is produced as seen in both figures 5 and 6.

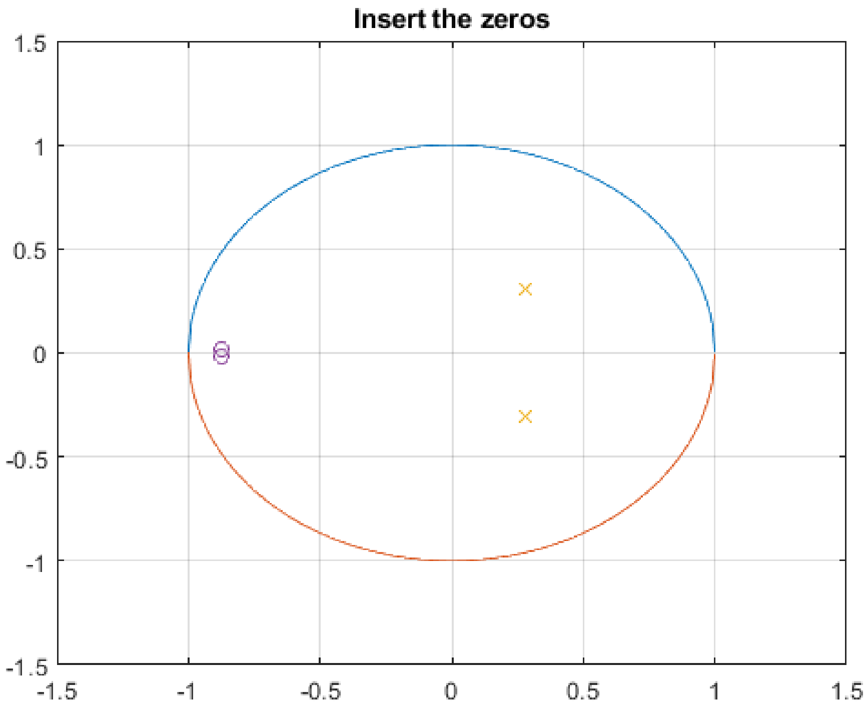

Figure 5: User Designated Zeros Placed on Pole Zero Graph

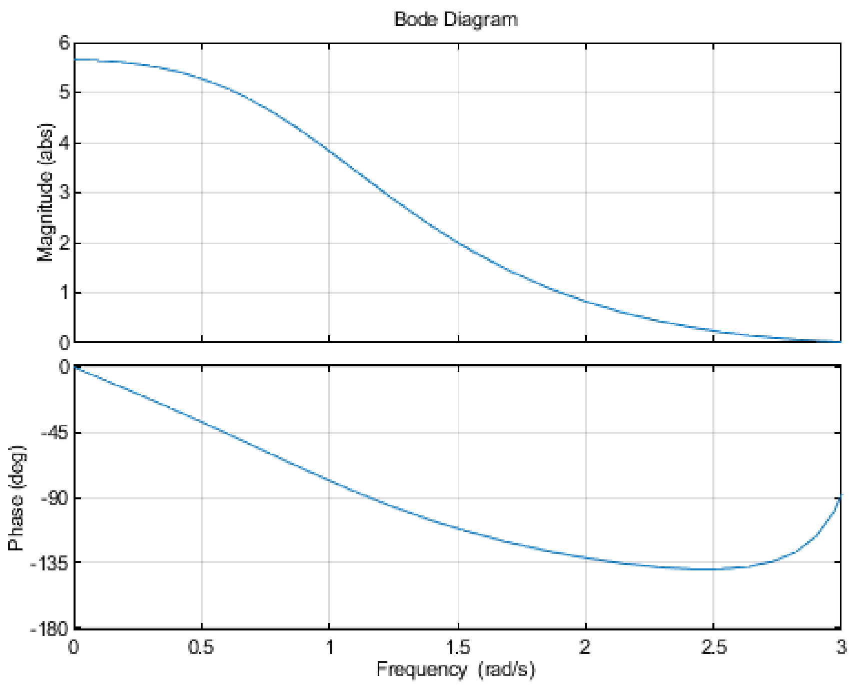

Figure 6: Frequency Response of the Filter

Here it can be seen that the filters response was produced. Looking at the reference pole zero diagrams in figure 1, the correct output can be validated. The poles and zeros replicate a pole zero diagram such as the top left one and the output produced is indeed a low pass filter. The frequencies that pass through the system are of lower frequencies while high frequency signals will not be seen on the output.

4 Program Validation

Here I will provide a few additional images validating the correct operation of the program.

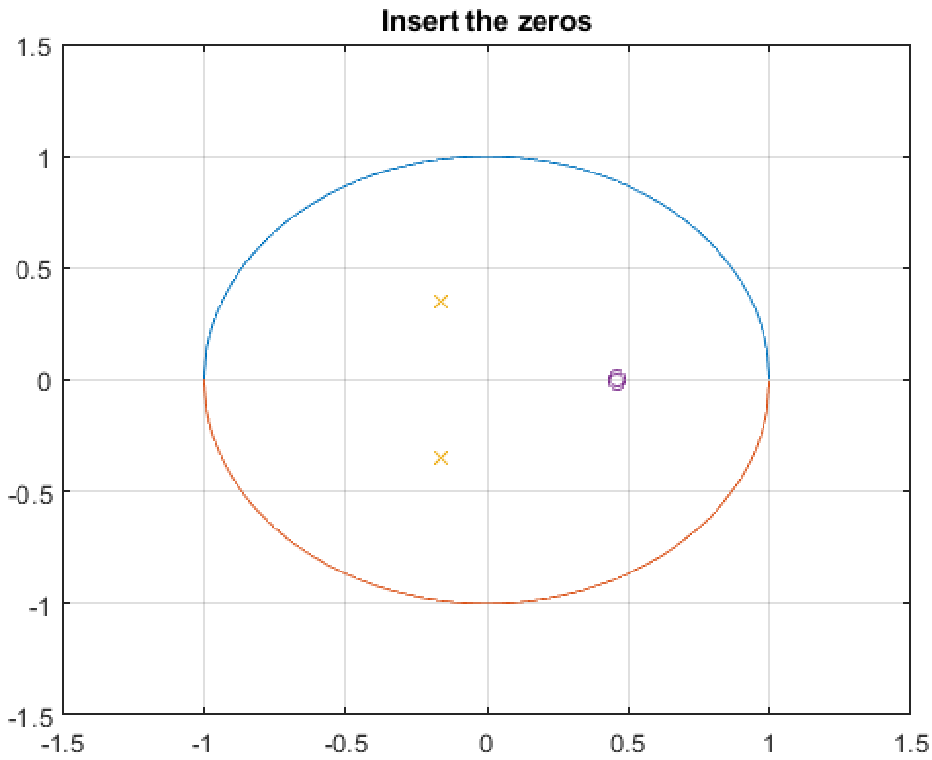

Figure 7: High Pass Filter Pole Zero Diagram

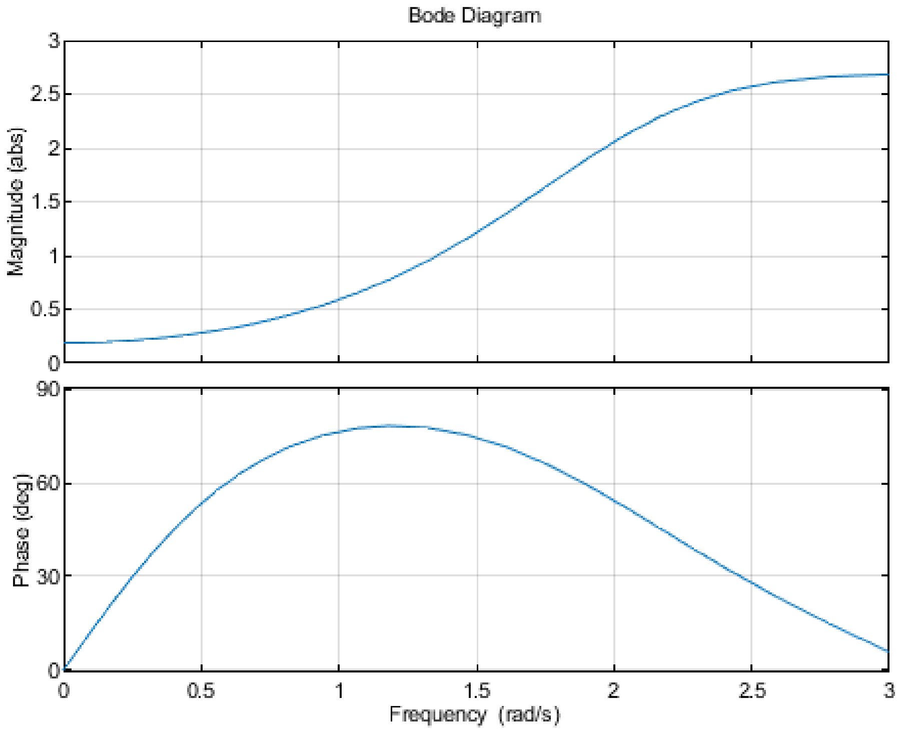

Figure 8: High Pass Filter Frequency Response

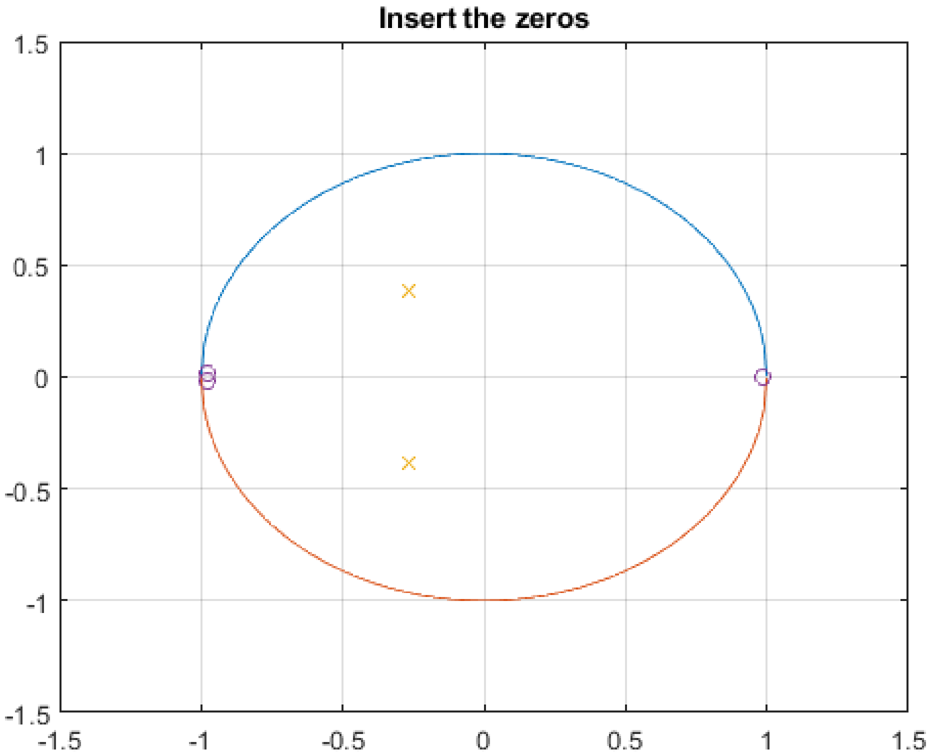

Figure 9: Band Pass Filter Pole Zero Diagram

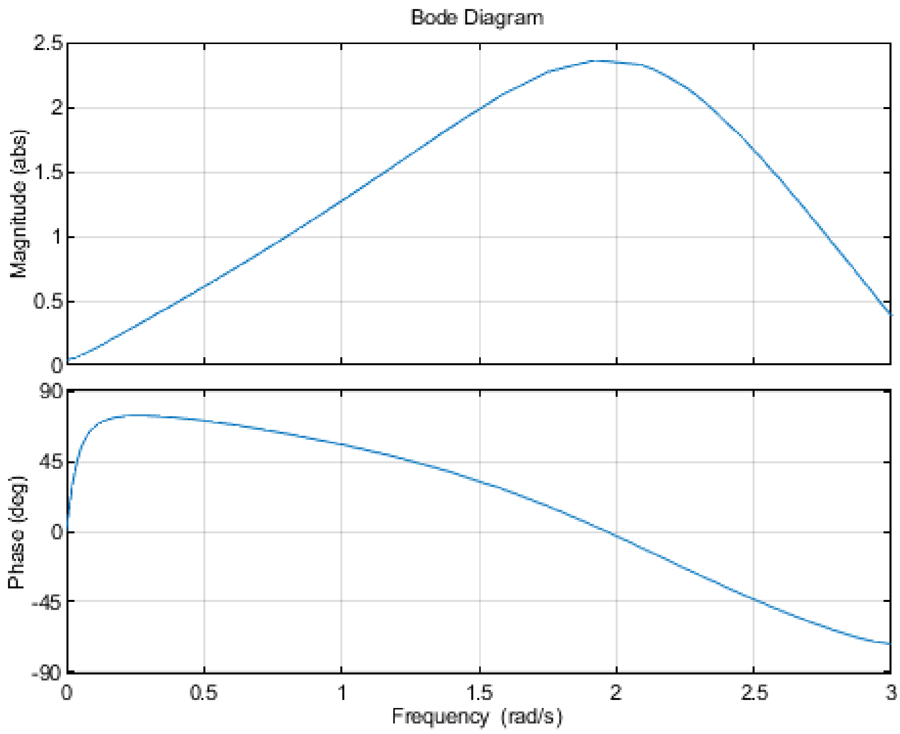

Figure 10: Band Pass Filter Frequency Response

The figures above provide evidence of proper operation. Figure 8 indicates a high pass filter output only allowing signals with high frequencies to pass through the system. Figure 10 shows the band pass filter output that was produced by its corresponding pole zero plot. This graph output also follows the expected result, only allowing frequencies within the middle of the range through the system.

5 Future Applications

This project helped develop my understanding for the applications MatLab has to my major. The reason for taking this course for me was to increase my exposure to MatLab and its use cases. I feel like this project was great for improving my confidence in applying MatLab to problems related to my major. I feel this program could have uses in the future for me. Being able to easily produce the frequency response of a filter based on its poles and zeros could be valuable in future classes allowing me to double check the work I have produced. Additionally, I feel like the understanding I developed will allow me to produce additional MatLab programs and algorithms related to some of the common design problems that come up in my major. This will make it easier to solve these problems and develop solutions that can be easily verified.

References

[1] MatLab, The MathWorks Inc. Natick, Massachusetts.

[2] N. Redmond, "Pole-zero placement." https://www.earlevel.com/main/2003/02/27/pole-zero-placement/, 2003.