Student: Garrett Nadauld

Course: ECE 5210

Subject: Lab 6, All-pass Systems

Date: March 29, 2024

1 Introduction

In this lab, we explore the implementation and analysis of all pass systems on STM32F769I development boards, a foundational tool in digital signal processing. Through theoretical insights and practical experimentation, we aim to understand the behavior of the filter and its performance in real-time signal processing applications.

We will be implementing the system using C and using the oscilloscope to plot the phase and magnitude of the frequency response by performing a frequency sweep. We can then compare the measured frequency response with the numerical and analytical solutions

2 Theory

This lab required the calculation of the zeros as well as the all-pass system and the minimum phase system. The total system equation looks like

$$H(z) = (0.1)(1+z^{-1})\left(1-0.8e^{j\frac{\pi}{4}}z^{-1}\right)\left(1-0.8e^{-j\frac{\pi}{4}}z^{-1}\right)\left(1-1.25e^{j\frac{\pi}{4}}z^{-1}\right)\left(1-1.25e^{-j\frac{\pi}{4}}z^{-1}\right)...$$

$$...\left(1-0.4e^{j\frac{4\pi}{5}}z^{-1}\right)\left(1-0.4e^{-j\frac{4\pi}{5}}z^{-1}\right)\left(1-2.5e^{j\frac{4\pi}{5}}z^{-1}\right)\left(1-2.5e^{-j\frac{4\pi}{5}}z^{-1}\right) \tag{1}$$

Decomposing this equation into the all-pass and minimum phase components yields

$$Hap(z) = \frac{(z^{-1}-0.8e^{j\frac{\pi}{4}})(z^{-1}-0.8e^{-j\frac{\pi}{4}})(z^{-1}-0.4e^{j\frac{4\pi}{5}})(z^{-1}-0.4e^{-j\frac{4\pi}{5}})}{(1-0.8e^{j\frac{\pi}{4}}z^{-1})(1-0.8e^{-j\frac{\pi}{4}}z^{-1})(1-0.4e^{j\frac{4\pi}{5}}z^{-1})(1-0.4e^{-j\frac{4\pi}{5}}z^{-1})} \tag{2}$$

$$Hmin(z) = (0.1\cdot 1.25^2\cdot 2.5^2)\cdot(1-0.8e^{j\frac{\pi}{4}}z^{-1})^2(1-0.8e^{-j\frac{\pi}{4}}z^{-1})^2(1-0.4e^{j\frac{4\pi}{5}}z^{-1})^2(1-0.4e^{-j\frac{4\pi}{5}}z^{-1})^2...$$

$$...(1+\mathrm{z}^{-1}) \tag{3}$$

3 Results

The results for this lab can be seen in Fig.1 and Fig.3. Fig.1 shows the zeros of our transfer function plotted on the unit circle. In Fig.3 there are two subplots, each containing six lines. Each line corresponds to the measured data and the analytical solution for each of the transfer functions. Each plot analytical plot lines up with the measured plot pretty well but there is some variation.

4 Discussion and Conclusions

This lab was really easy to implement which made it one of my favorites. We got stuck on an issue with one of the SciPy modules we were using but other than that it was really straighforward. The reason our analytical and measured data are off from one another even after phase correction is because of our step size. In some spots it jumps to a value that is a ways off from the analytical solution which I attribute to not enough data points on the frequency sweep. Bumping up the number of samples might fix this but a step size was given in the lab so that is what I went with.

The magnitude and phase plots for H_{min} and H_{ap} are as expected. The all pass system has zero gain and the phase is similar but slightly shifted. The minimum system has a magnitude that matches the total system exactly and a phase that is minimized throughout the plot. $h[n]$ and $h_{min}[n]$ are interesting, because the impulse response for the minimum system appears to have similar magnitudes as the overall system but the larger magnitudes are focused at the start and end with the lower magnitudes.

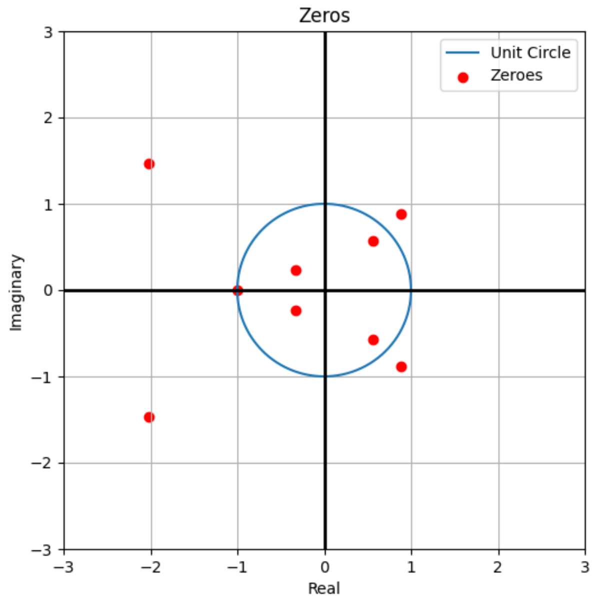

Figure 1: Zeros of our total system

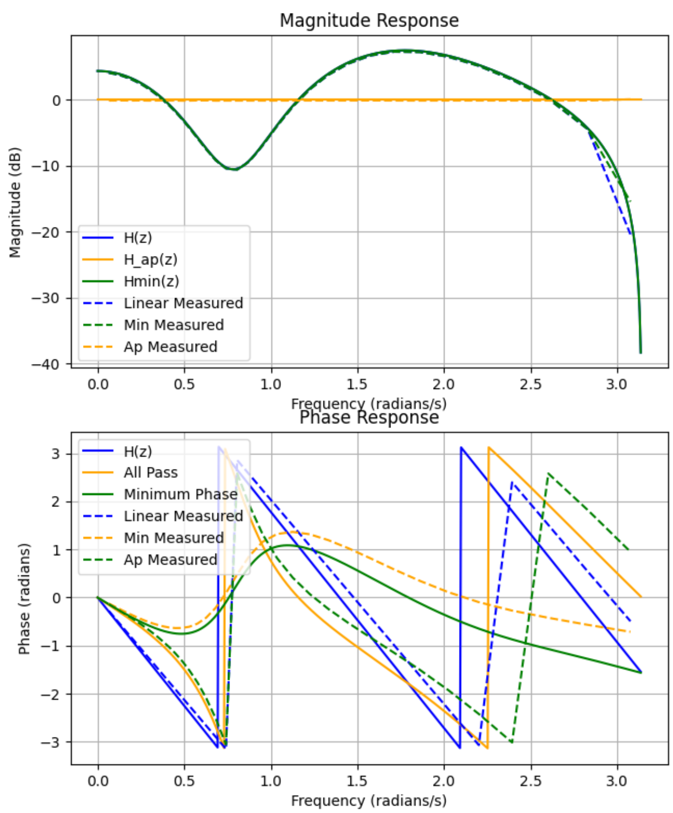

Figure 2: Magnitude and phase of the frequency response using measured and analytical data

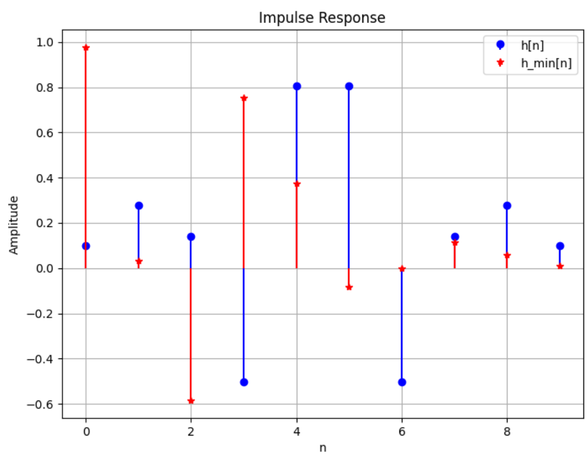

Figure 3: Impulse response for $h[n]$ and $h_{min}[n]$