Signal Processing Report

Problem Description

We are tasked with designing a low-pass filter to filter high-frequency noise from a signal. This process includes choosing $\delta_s, \delta_p, \omega_s, \omega_p$ to calculate the order N, and ω_c. It is given that $\delta_s = -25dB \ and \ \delta_p = -1dB$. Additionally, $N \leq 10$. These values of N and ω_c should then be used to calculate A and B for a difference equation. These values for A and B should be used to rerun the microcontroller code to test the results.

Filter Design Calculations

Because I did not want to risk the possibility of getting a value of N above 10, I implemented the calculations in Desmos. I made https://www.desmos.com/calculator/mkug4xf6ef. This way I could adjust ω_s and ω_p until I get good values of N and ω_c.

$$w_p = p_p \cdot x$$

$$w_p = 0.204$$

$$w_s = p_s \cdot x$$

$$w_s = 0.714$$

$$d_{pdb} = -1$$

−40 0

$$d_{sdb} = -25$$

−40 d_{pdb}

$$d_p = 10^{\frac{d_{pdb}}{20}}$$

$$d_p = 0.891250938134$$

$$d_s = 10^{\frac{d_{sdb}}{20}}$$

$$d_s = 0.056234132519$$

$$k_p = \frac{1}{d_p^2} - 1$$

$$k_p = 0.258925411794$$

$$k_s = \frac{1}{d_s^2} - 1$$

$$k_s = 315.227766017$$

$$N = \operatorname{ceil}\left(\frac{1}{2} \cdot \frac{\log\left(\frac{k_s}{k_p}\right)}{\log\left(\frac{w_s}{w_p}\right)}\right)$$

$$N = 3$$

$$w_c = \frac{w_p}{k_p^{\frac{1}{2N}}}$$

$$w_c = 0.255525583189$$

N = 3, Oc = 0.2555

A & B Coefficients

As per the instructions, I implemented this code in MATLAB following the given instructions. I cleaned up some of the code and changed N and Oc to my previously calculated values.

I will note that for some reason my c2d() function provides slightly different results than from the instructions. My tf() function provides the same continuous transfer function but, when converting to a digital version, the denominator is the same as shown but my numerator is slightly different. This can be due to many things, but the results are still mostly correct.

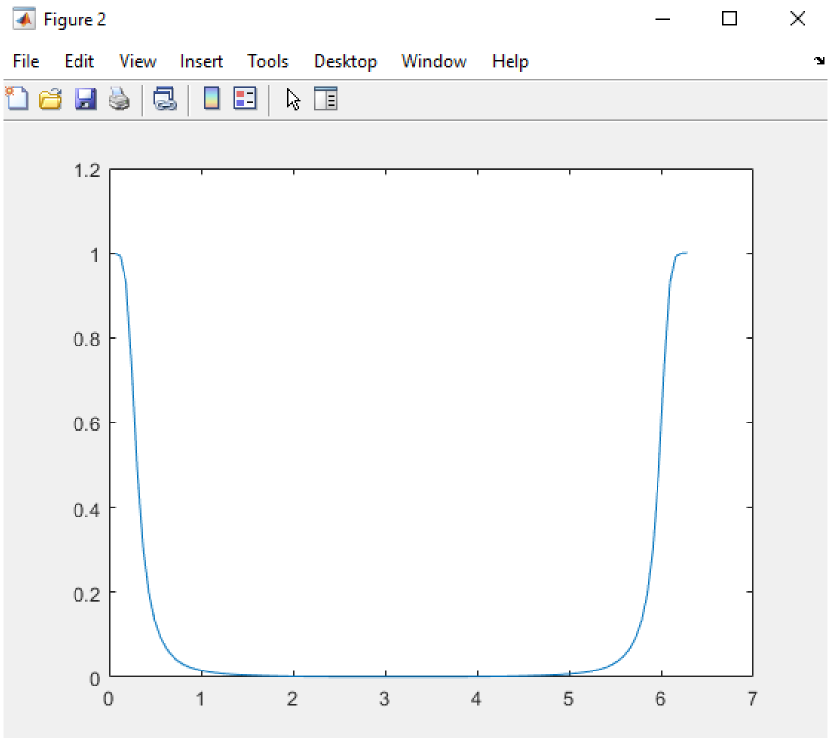
When N is large, the A and B lists still filters as expected, but the magnitude of the resulting signal is increased. This might be due to precision errors or due to the different results from c2d() on my computer. Either way, I decided to keep N within a reasonable range ($N<4$) to have reasonable results. I tried multiple ways to allow N to be large and to have it still work, but to no avail.

I'll include my MATLAB file in case c2d() works differently on your computer.

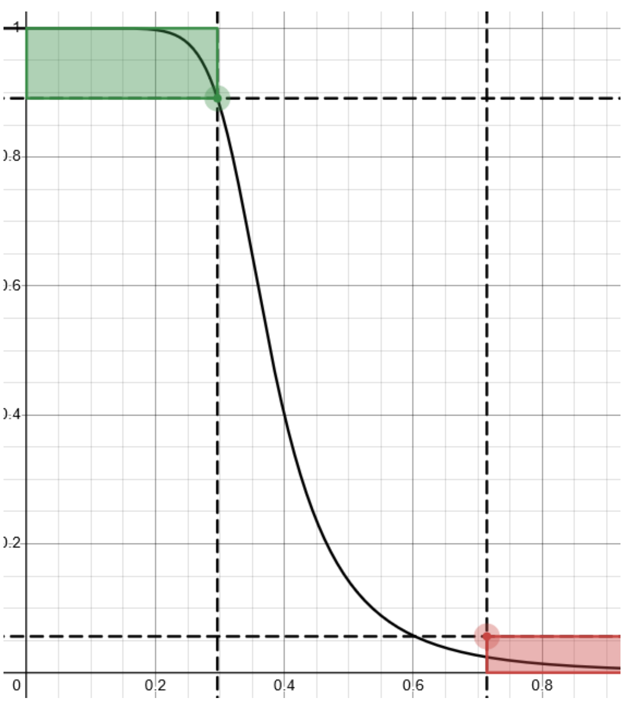
A = 1.0000 -2.4918 2.1046 -0.5999

B = 0 0.0024 0.0086 0.0019

Abs(H) Plot



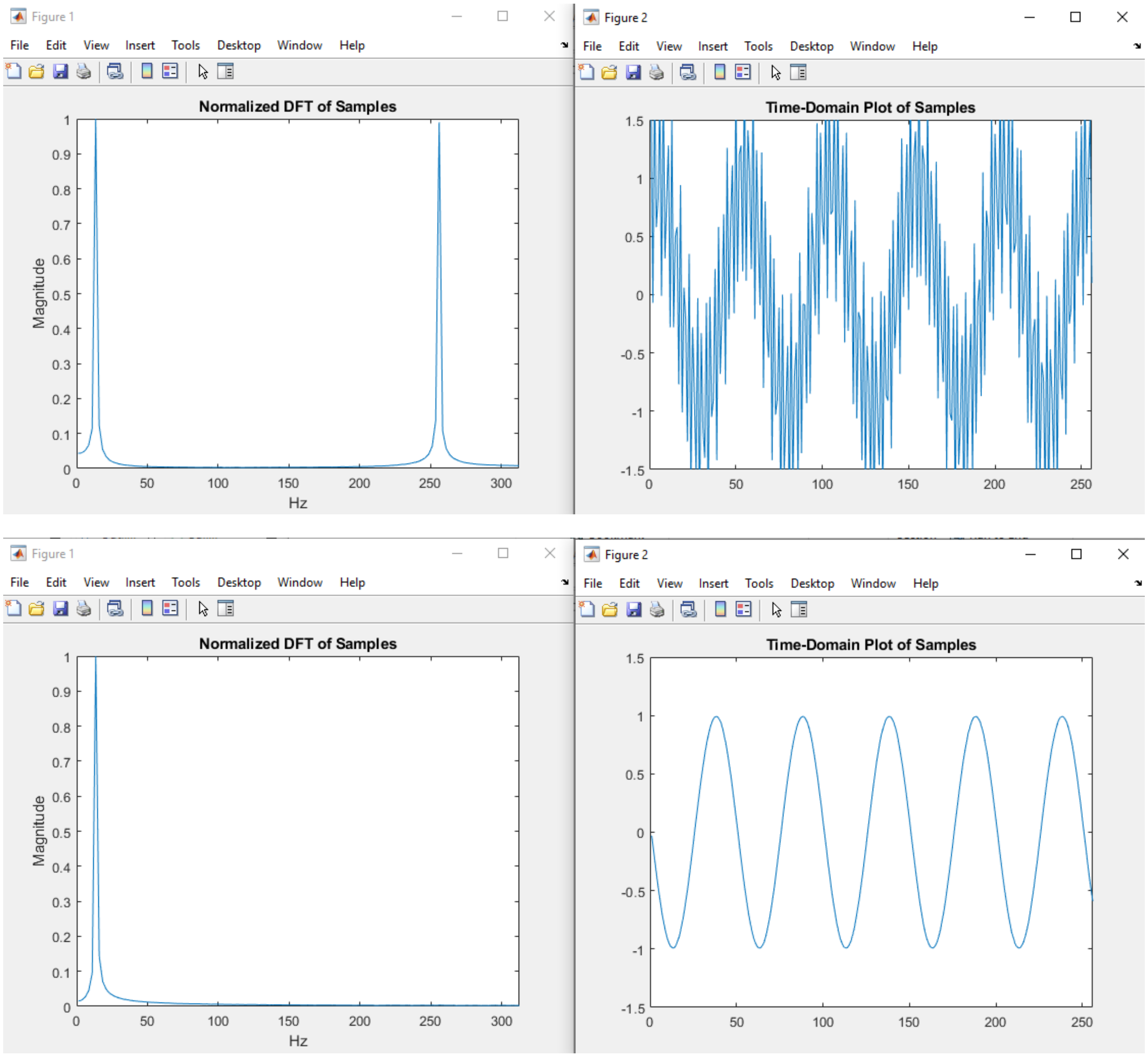
My Desmos code shows the Butterworth function with the filter boxes overlapped.



Main.c

Same as previous assignment but with different values for A and B. File is included in the zip.

Microcontroller Plots



I removed the secondary line showing the filter magnitude due to it using butter(). The function butter() gives better (see A&B coef. section) but different results from the difference equation using the calculated A and B.