EE 141 DIGITAL SIGNAL PROCESSING

Lab 3: Basic Second Order Filters

In this lab, we will gain hands on experience processing a real-world music signal. Recall from class that second order transfer functions of the form

$$H(z) = \frac{c}{(1 - az^{-1})(1 - a^{*}z^{-1})}$$

with ROC: $|z| > |a|$ can be used as simple lowpass, bandpass, or highpass filters. The kind of filter is determined by the location of a inside the unit circle.

Before starting the lab, download the .MAT file provided on iLearn and load it typing

```
load ride
```

This will load a $1,000,000 \times 2$ vector named `audio_sample` and a variable `fs` to the workspace. This is a stereo music signal with sampling rate $f_s = 44,100$Hz, each column representing one channel (left or right). To play this, one needs to type

```
p = audioplayer(audio_sample,fs);
```

followed by `play(p)`

a) For general a and c, determine the impulse-response $h[n]$.

b) Appropriately choosing a, design a lowpass filter. Using the `conv` command, convolve both left and right channels with $h[n]$ and write the output to a stereo signal $y_L[n]$. Aside from choosing a properly, set c to a value such that $H(e^{j\omega})$ becomes 1 at $\omega = 0$. That way, rather than boosting low frequencies, you will suppress high frequencies. Play the output audio. Do you hear a muffled version of the original audio file?

c) Using the `fft` command, take the DTFT of both the input and the output of one of the channels (say left). Plot their magnitudes side by side. For example, if you named the DTFT vector `X`, you need to type `plot(fftshift(abs(X)))` for this. The extra `fftshift` is for centering the zero frequency in the plot. You might also want to zoom in, especially on the y-axis, and make sure you have the same scale on the two graphs. Do you see that the high frequencies are suppressed?

d) Repeat **b** and **c** with a highpass filter. You need to similarly set c such that $H(e^{j\omega}) = 1$ at $\omega = \pi$. Do you hear a file where high frequencies are more prominent?

e) Repeat **b** and **c** with a bandpass filter. This time, you need to set a to a purely imaginary value close to j (e.g., $a = 0.9j$). Also set c such that $H(e^{j\omega}) = 1$ at $\omega = \frac{\pi}{2}$.