Digital Signal Processing

# Laboratory 4 Frequency Response

## 4.1 Introduction

The purpose of this lab[1] is to investigate a method of computing the frequency response of an LTI system described by a difference equation.

## 4.2 Frequency Response

Given a rational transfer function, the `freqz` function can be used to find its frequency response.

The command `w,h = scipy.signal.freqz(b,a,N,whole=True)` will evaluate the frequency response of the filter at $N$ points, equally spaced in radian frequency around the unit circle. If `N` is not used, 512 frequencies around the unit circle will be computed. If the `whole` option is not used, then `freqz` will use only the upper half of the unit circle (from 0 to $\pi$ in frequency). The output vectors `w` and `h`, will return `N` frequency response samples (in `h`) and `N` equally spaced values of $\omega$ from 0 to $2\pi$ or 0 to $\pi$ (in `w`).

### 4.2.1 EXERCISE

For each of the difference equation:

$$y(n) = \tfrac{1}{2}\left[x(n) - 0.5x(n-1)\right] \tag{4.1}$$

$$y(n) = \tfrac{1}{2}\left[x(n) + x(n-1)\right] \tag{4.2}$$

$$y(n) = \tfrac{1}{2}\left[x(n) - x(n-2)\right] \tag{4.3}$$

$$y(n) = \tfrac{1}{2}\left[x(n) + x(n-2)\right] \tag{4.4}$$

$$y(n) - 1.8\cos(\tfrac{\pi}{16})y(n-1) + 0.81y(n-2) = x(n) + \tfrac{1}{2}x(n-1) \tag{4.5}$$

do the following frequency-domain computations.

1. Make plots of the magnitude and phase response, with 512 frequency samples around the entire unit circle. For instance, use `plot(w,abs(h))` or `plot(w,angle(h))`.

2. Make plots of the magnitude and phase response, using only the upper half of the unit circle ($\omega$ ranges from 0 to $\pi$).

[1] S. Burrus, etal., *Computer-Based Exercises for Signal Processing using Matlab*, Prentice-Hall: Englewood Cliffs, NJ, 1994, pp.12-13

3. Specify the type of filter defined by this difference equation: high-pass, low-pass, all-pass, bandpass, or bandstop.

### 4.2.2 EXERCISE

For the following difference equations, plot the magnitude and phase response and state what type of filter it defines:

1. $y(n) + 0.13y(n-1) + 0.52y(n-2) + 0.3y(n-3) = 0.16x(n) - 0.48x(n-1)$ $+ 0.48x(n-2) - 0.16x(n-3)$
2. $y(n) - 0.268y(n-2) = 0.634x(n) - 0.634x(n-2)$
3. $y(n) + 0.268y(n-2) = 0.634x(n) + 0.634x(n-2)$
4. $10y(n) - 5y(n-1) + y(n-2) = x(n) - 5x(n-1) + 10x(n-2)$

I will highly appreciate your comments and suggestions to improve this material.
R. Stephen L. Ruiz rslruiz@gmail.com