Signal Processing and Speech Communication Lab.
Graz University of Technology

SV

Assignment 2

This homework has to be submitted via **e-mail** to the address `hw1.spsc@tugraz.at` **not later than 6.6.2018**. Let the **subject** of the e-mail be "YourMatrNo YourColleague'sMatrNo". The body of the e-mail should be empty (nobody will read it). A complete project consists of Matlab/Octave files (`*.m`) and a simulation protocol in PDF format. You have to **zip** all these files to a single file with name

`YourMatrNo_YourColleague's MatrNo.zip`

which has to be attached to the e-mail.

In addition to the email, you have to throw your printed (**paper format**) **simulation protocols and your analytic solutions** into our **mailbox at Inffeldgasse 16c**, ground floor, not later than 6.6.2018 (note that you cannot access the mailbox on weekends). For each problem, staple your solutions separately. Use the print-out of the respective problem assignment as the title page(s). Don't forget to fill in your **name(s)**, **matr. number(s)**, and **group number(s)**.

If you typeset your analytic solutions with LaTeX, you can get bonus points. If you submit a handwritten protocol, be aware that it should be clear, tidy and readable. Otherwise, you will lose points.

Name(s) Matr.Nr. **SV**

Analytic Problem 2.1 (10 points)

(a) [2 point(s)] Solve following tasks:

1. Simplify $e^{j\pi} \cdot \cos(3\pi/2) + j\sin(3\pi/2)$.
2. Solve the quadratic polynomial for x: $(x^2+6)^2 - 21 = 4 \cdot x^2 + 15$
3. Simplify $\sum_{n=-\infty}^{\infty} e^{-j\theta n}\frac{1}{3}(\delta[n] + \delta[n-1] + \delta[n-2])$.
4. Calculate $H(z)$ using $Y(z) = \frac{1}{(1+z^{-2})} \cdot [X(z) + \frac{(1+z^{-1})\cos(\theta)}{1-cos(\theta)z^{-1}}(X(z) + Y(z)(z^{-1} - z^{-2}))]$.

(b) [4 point(s)] Describe in words the linear and the circular convolution between two non-periodic sequences $x_1[n]$ and $x_2[n]$. What is the difference? How can the circular convolution be interpreted? Now consider the sequences in Figure 1 and 2. What is the length N_{x1} of $x_1[n]$ and length N_{x2} of $x_2[n]$? Determine analytically and graphically:

1. Linear convolution $y_1[n] = (x_1 * x_2)[n]$
2. Circular convolution $y_2[n] = (x_1 \overset{N}{*} x_2)[n]$. Within the circular convolution you will need the modulo-Operation $n \mod N$ with an additional Parameter N. Choose $N = 8, 7, 2$. What happens with changing N?

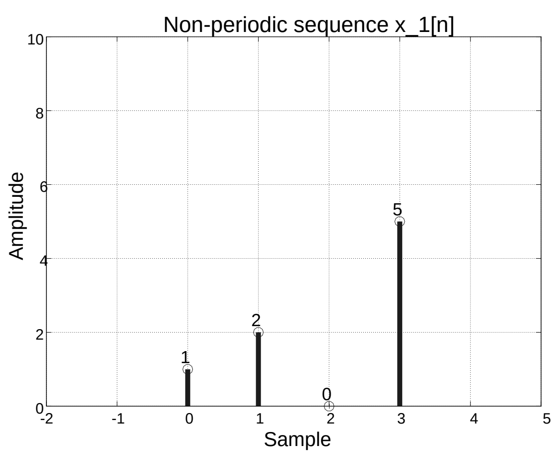

Figure 1: $x_1[n]$

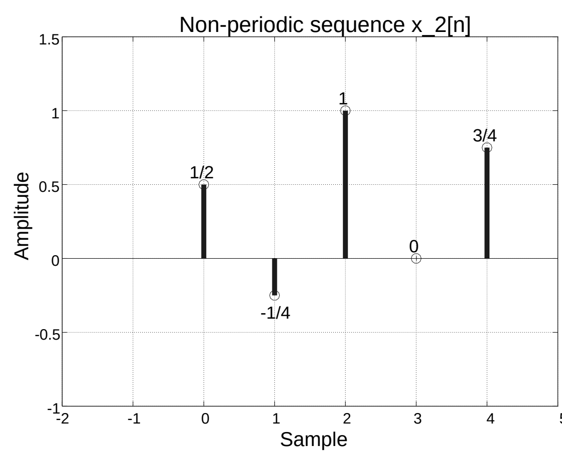

Figure 2: $x_2[n]$

(c) [4 point(s)] Let

$$h[n] = -h[M-n], \quad 0 \leq n \leq M$$

be an asymmetric impulse response of an FIR filter. $h[n]$ is 0 for $n < 0$ and $n > M$.
It can be shown that such a filter will have a linear phase response. Derive $H(e^{j\theta})$ for a given $h[n]$ when M is even. Sketch the frequency response (amplitude and phase) for $h[n] = [1, 0, -1], \quad n = 0, 1, 2$. Which kind of filter can be realized?

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Analytic Problem 2.2 (8 points)

(a) [4 point(s)] Let $h[n]$ be an discrete-time impulse response of a causal linear time-invariant (LTI) system. Many properties can be derived from the pole-zero representation of $H(z)$. Describe the characteristics of the pole-zero representation that corresponds to the following properties and give one example each:

1. FIR filter (finite impulse response)
2. Real-valued impulse response
3. Minimum phase
4. All-pass

(b) [4 point(s)] The stable signal $y[n]$ with a Z-transform $Y(z)$ is the output of a linear time-invariant (LTI) system with impulse response $h[n]$ for a given stable input $x[n]$ with a Z-transform $X(z)$.

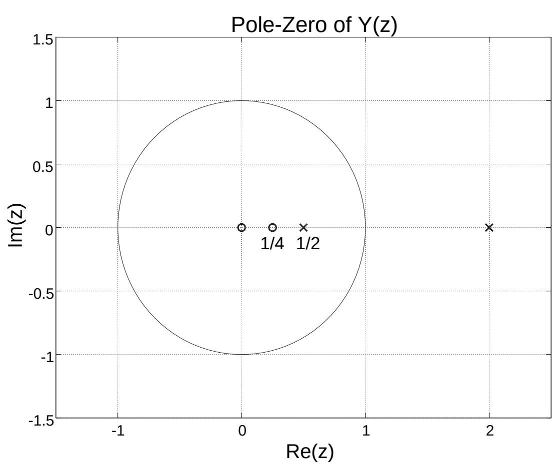

Figure 3: Pole-Zero Diagram of $Y(z)$

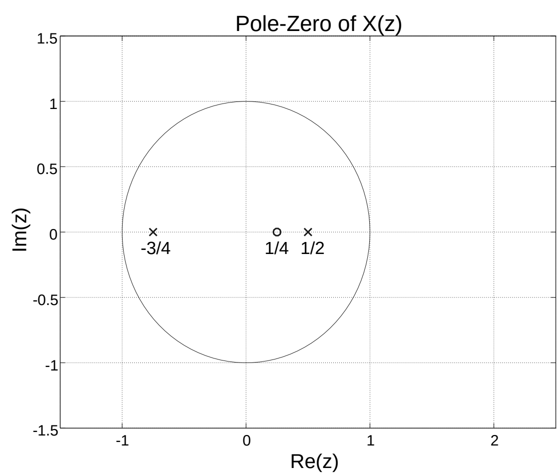

Figure 4: Pole-Zero Diagram of $X(z)$

Answer following questions:

1. What is the ROC of $X(z)$ and $Y(z)$?
2. Is $y[n]$ a left-sided, right-sided or two-sided signal?
3. What is the definition of a causal sequence? Is $x[n]$ a causal sequence?
4. Calculate $x[0]$.
5. Sketch the pole-zero diagram of $H(z)$. What is the ROC of $H(z)$?
6. What is the definition of an anti-causal sequence? Is $h[n]$ an anti-causal sequence?

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Octave Problem 2.3 (15 points)

In the attachment of the assignment you can download a file called *HE01FNS00101_n.wav*. The input data sequence $y[n] = x[n] + d[n]$ in the file consists of a speech signal $x[n]$ which is disturbed by additive noise $d[n]$. In this task we want to load and analyze the input sequence. Afterwards a filter should be designed, which is able to remove the disturber $d[n]$. In the last point we want to realize the filtering using fast convolution and block processing.

(a) [5 point(s)] Load $y[n]$ using e.g. `wavread`. What is the sampling frequency f_s of the signal? Calculate the discrete Fourier-transform using `fft`. Plot the signal in time and frequency domain with x-axis in seconds and Hz. Add labels and title. You can use the commands `xlabel, ylabel, title, axis, xlim, ylim,...`. Also use Help by typing e.g. `help fft`.

(b) [1 point(s)] Listen to the input sequenze $y[n]$ and analyze the plots: Describe the property of the disturber $d[n]$ and find a mathematical representation.

(c) [1 point(s)] Design a highpass filter with order = 600 and cut of frequency $f_c = 300$. Create the filter coefficients with the function `fir1`. What kind of filter is it? Plot the transfer function using `freqz`.

(d) [2 point(s)] Filter the input signal $y[n]$ using `filter`. How does order and f_c influence the result? Experiment with different values.

(e) [2 point(s)] Describe the fast convolution approach. Furthermore implement fast convolution and make sure that the result is the same than in task (d).

(f) [4 point(s)] Now we want to block process the filtering. Therefore, write an own function `sequence2block(signal, N)` to separate the signal $y[n]$ into blocks of length N. Afterwards apply the filter designed above to each block in order to obtain the filtered output signal. Describe the effect of the block processing and how to remove the artifacts.

In general: Make sure to write readable code and to document the steps. Write headers and descriptions to the functions. Furthermore, produce representing pictures using appropriate font size, line width and labels.