**Exercise 2: System fundamentals**

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| **Group** |
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[**Read these instructions first!**](https://docs.google.com/document/d/1XSXjrRHB4QzoYnxU58mu5CHzkpJkwTsINSc6WigQq4k/edit?usp=sharing)

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| # | Questions | Write your answer in this column |
| 1 | Check if the following systems are **linear**​:   1. y​1[​ n] = F{x[n]} = x[n] + 3 2 2. y​2[​ n] = x​​[n] 3. y​3[​ n] = ¼ ​(x[n]+2\*x[n-1]+x[n-2]) 4. y​4[​ n] = n·x[n]     Hint: System is linear iff F{a·x1​ [n]+b·x​ 2​ [n]} =​ a·F{x1​ [n]}+b·F{x​ 2​ [n]}​  Calculate the rms-difference of left- and right-hand side equation using random signal sequences and random scaling factors a and b. | *Write your answer and justify it for example by adding the Matlab commands* |
| 2 | Check if the following systems are **causal**​:   1. y​1[​ n] = F{x[n]} = x[n] + 3 2 2. y​2[​ n] = x​​[n] 3. y​3[​ n] = ¼ ​(x[n]+2\*x[n-1]+x[n-2]) 4. y​4[​ n] = n·x[n]     Hint: System is causal iff there is no action before reaction | *Write your answer and justify it for example by adding the Matlab commands* |

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|  | x[n] = 0 , ∀ n ≤ 0 ⇒ F{x[n]}  = 0, ∀ n ≤ 0  Use random signal sequence, which starts at n = 0. Observe the system output for negative n. |  |
| 3 | Check if the following systems are **time-shift invariant**​:   1. y1​ [​ n] = F{x[n]} = x[n] + 3 2 2. y2​ [​ n] = x​ [​ n] 3. y3​ [​ n] = ¼ (​ x[n]+2\*x[n-1]+x[n-2]) 4. y4​ [​ n] = n·x[n]     Hint: System is time-shift invariant iff delay of output = output of delayed signal  D{ F{x[n]} , k} = F{ D{x[n], k} }  Use random signal sequence, which starts at n = 0. | *Write your answer and justify it for example by adding the Matlab commands* |
| 4 | Determine the difference equation for the following system      Hint: Follow the signal flow | *y[n] = …*  y[n] = x[n - 2] - 0.4y[n - 2] + 2x[n-1] + 0,139y[n - 1] + x[n] |
| 5 | What are the system parameters ​**a** and ​**b**​?    Hint: ​ k=0..N​ a​​ky[n-k] = ​ ​k=0..Nb​​kx[n-k]​ | *Write the Matlab commands to generate vectors for system parameters. Be careful here, since two of the most common mistakes are done on this exercise!*  a=[1 -0.139 0.4];  b=[1 2 1]; |
| 6 | Calculate zeros and poles, and determine is the system stable | *Draw zeros and poles on Argand’s diagram*  %Y(z)  a=[1 -0.139 0.4];  %X(z)  b=[1 2 1];    %Calculate zeros and poles  zplane(a,b) |
|  |  | *Is the system stable?*    *No, because poles are not inside unit circle.* |
| 7 | Determine the parameters ​**a** and ​​**b**​ for the following system:    y[n] = ​⅛\*x[n]+⅜\*x[n-1]+⅜\*x[n-2]+⅛\*x[n-3] | *Write the Matlab commands to generate vectors for system parameters*  a = [ 1 0 0 0];  b = [1/8 3/8 3/8 1/8]; |
| 8 | Calculate zeros and poles, and determine is the system stable | *Draw zeros and poles on Argand’s diagram*    %Y(z)  a = [1 0 0 0];  %X(z)  b = [1/8 3/8 3/8 1/8];    %Calculate zeros and poles  zplane(a,b)  *Is the system stable?*      *No, beacuse poles are not inside unit circle.* |
| 9 | Generate a sound sample which consists of   * 22050s​-1​ sampling rate * 250 samples * Sine wave   ○ Amplitude 0.25  ○ Signal frequency  **SSS**​**/2**​​Hz   * Add random noise with amplitude = [​**SSS**/800]​ | *Stem plot the signal*  %DPS Problem Solving 2    %Exercise 2.9    SSS = 139; %SSS  A = 0.25; % amplitude of the base sig.  smpls = 1:250; % samples = 250  f = SSS/2; % base signal freq.  fs = 22050; %smapling freq.  An = SSS/800; %amplitude of the noise sig.    %base signal  yb = A\*sin(2\*pi\*f\*smpls/fs);  %noise signal  yn = (An\*rand(1,250));    %base sine wave signal with noise  y = yb+yn;    %stem plot sine wave  stem(smpls,y) |
| 10 | Use the previous signal as input for the system in question 2.7. Compare the input and output signal and observe how the system modifies the signal. | *Plot the signals on the same graph.*    *What does the system Q2.7 do for the signal?*  *System works as a filter. It filters some of the noise out from the input signal.*  %DPS Problem Solving 2    %Exercise 2.10    SSS = 139; % SSS  A = 0.25; % amplitude of the base sig.  smpls = 1:250; % samples  f = SSS/2; % base signal freq.  fs = 22050; %smapling freq.  An = SSS/800; %amplitude of the noise sig.    %base signal  yb = A\*sin(2\*pi\*f\*smpls/fs);  %noise signal  yn = (An\*rand(1,250));    % base sine wave signal with noise  y = yb+yn;    % vector containing results  z = zeros(1,250);    z(1)=1/8\*y(1);  z(2)=1/8\*y(2)+3/8\*y(1);  z(3)=1/8\*y(3)+3/8\*y(2)+3/8\*y(1);    % for loop: loops from 4 to 249  for i = 4:249    % difference equation  z(i)=1/8\*y(i)+3/8\*y(i-1)+3/8\*y(i-2)+1/8\*y(i-3);    end    % original signal with noise  figure(1)  stem(smpls,y)    % difference equation output, using original signal as input  figure(2)  stem(smpls,z) |