

EE3210 Signals and Systems

MATLAB Exercise 1

Hands-On Learning for Signals and Systems

Intended Learning Outcomes:

On completion of this MATLAB exercise, you should be able to

- Generate and visualize simple signals
- Perform fundamental operations and analyses for signals and systems

Deliverable:

- Each student is required to submit a **short report** to canvas which includes your answers for questions and findings for this computer exercise on or before **21 Feb. 2024**.

Procedure:

If you are not familiar with MATLAB, you can view the MATLAB introduction by typing `intro` at the MATLAB prompt. This short introduction will demonstrate some of the basics of using MATLAB. Or you can explore the MATLAB help capability which is available at the command line, such as `help`, `help plot` and `help clear`, where `plot` and `clear` are command names. Apart from a number of MATLAB reference books such as [1]-[2] which can be found in City University's library, many on-line MATLAB resources, including [3]-[4], are available.

1. Generate and plot $x[n] = 2\cos(0.2\pi n)$ for $0 \leq n \leq 99$ using the following MATLAB code:

```
clear all
n=[0:99];
x=2*cos(0.2*pi.*n);
stem(n,x);
legend('x[n]');
title('Sequence of periodic signal');
xlabel('n');
ylabel('x[n]');
axis([0 99 -2 2]);
```

Examine the operation of each command line. Then answer the following:

- (a) How many periods of the sinusoidal sequence are there in the plot?
- (b) Determine the fundamental frequency and fundamental period of $x[n]$.
- (c) Compute the power of $x[n] = 2\cos(0.2\pi n)$.
- (d) Suppose $x[n] = 0$ outside the interval $0 \leq n \leq 99$. With the use of MATLAB, compute the energy of $x[n]$, which is defined as:

$$E_{x,100} = \sum_{n=0}^{99} x[n]x^*[n] = \sum_{n=0}^{99} |x[n]|^2$$

where * denotes the complex conjugate operator. (Hint: You may use the complex conjugate transpose command “`'`” and matrix multiplication command “`*`” which are found using “`help ops`”.)

- (e) Repeat (d) with $x[n] = 2e^{j0.2\pi n}$, i.e., `x=2*exp(j*0.2*pi.*n)`.
- (f) Repeat (d) with $x[n] = 2\cos(0.2\pi n + 1)$.
- (g) Repeat (d) with $x[n] = 2\cos(0.222\pi n)$.
- (h) Repeat (g) with `n=[0:999]` and `n=[0:9999]`. Note that when $x[n]$ is of length N , the energy computation is generalized as:

$$E_{x,N} = \sum_{n=0}^{N-1} |x[n]|^2$$

2. Create a file named “`toneA.m`” with the following MATLAB code:

```
clear all
Fs=8000;
Ts=1/Fs;
t=[0:Ts:2];
F_A=440; %Frequency of note A is 440 Hz
A=sin(2*pi*F_A*t);
sound(A,Fs);
```

Type `toneA` at the command line and then answer the following:

- (a) What is the value of T_s ? What does T_s represent?
- (b) Modify `toneA.m` by changing “`A=sin(2*pi*F_A*t)`” to “`A=-sin(2*pi*F_A*t)`”. Can you hear any difference?
- (c) The frequencies of notes B, C#, D, E and F# are 493.88 Hz, 554.37 Hz, 587.33 Hz, 659.26 Hz and 739.99 Hz, respectively. Write a MATLAB file named “`song.m`” to produce a piece of music with notes in the following order : A, A, E, E, F#, F#, E, E, D, D, C#, C#, B, B, A, A. Assign the duration of each note as 0.3s.

3. Consider the following continuous-time signal:

$$x(t) = 3e^{-3|t|}, \quad -\infty < t < \infty$$

- (a) Compute the energy of $x(t)$ using the formula:

$$E_x = \int_{-\infty}^{\infty} |x(t)|^2 dt$$

- (b) Visualize $x(t)$ for $-10 \leq t \leq 10$ with the following MATLAB code:

```
t=-10:0.01:10;
x=3.*exp(-3.*abs(t));
```

```
plot(t,x)
```

Here, x represents the sampled version of $x(t)$. Write down the value of the sampling interval in converting $x(t)$ to x .

- (c) Integration can be approximated by summation. With the use of the sampling interval and x , compute an approximate value of E_x based on summation.

4. Generate

$$x[n] = 2 \cos(0.2\pi n + 1), \quad 0 \leq n \leq 63$$

using “ $x=2*\cos(0.2*pi.*n+1)$ ” with “ $n=[0:63]$ ”. Use the following MATLAB code to produce $y[n]$ from $x[n]$:

```
x1=[0 0 0 0 x];
x2=[0 0 0 x 0];
x3=[0 0 x 0 0];
x4=[0 x 0 0 0];
x5=[x 0 0 0 0];
y=(x1+x2+x3+x4+x5)/5;
y=y(1:64);
plot(n,x,'b',n,y,'r')
legend('x[n]','y[n]');
```

Answer the following questions:

- (a) Write an equation that relates $x[n]$ and $y[n]$ for $4 \leq n \leq 63$.
(b) State two differences between $x[n]$ and $y[n]$ for $4 \leq n \leq 63$.
(c) Try the following MATLAB code to generate $z[n]$ by passing $x[n]$ through a discrete-time system with impulse response $h[n]$:

```
h=[0.2 0.2 0.2 0.2 0.2];
z=conv(h,x);
z=z(1:64);
```

By plotting $z[n]$ and $y[n]$ together, determine if they are equal or not.

5. Given two discrete-time signals $x[n]$ and $h[n]$:

$$x[n] = \begin{cases} (0.5)^n, & 1 \leq n \leq 4 \\ 0, & \text{otherwise} \end{cases} \quad \text{and} \quad h[n] = \begin{cases} 2^n, & -1 \leq n \leq 2 \\ 0, & \text{otherwise} \end{cases}$$

Let $y[n]$ be the convolution of $x[n]$ and $h[n]$. Answer the following:

- (a) Use MATLAB to construct $x[n]$ and $h[n]$ and then compute $y[n]$. (Hint: use $\wedge$ and `conv`). Write down the values of $y[n]$ for all n .
(b) Plot $y[n]$ using the command `stem` and attach it in your report.

- (c) Try the command `deconv(y,x)` where `x` and `y` are the vectors for $x[n]$ and $y[n]$. If $x[n]$ and $y[n]$ represent the input and output of a system, respectively, what is the purpose of this command?
6. Let $x[n]$ and $y[n]$ be the input and output of a discrete-time system, respectively, and they are related by $y[n] = -ay[n-1] + x[n]$. Suppose $x[n] = u[n]$ which is the unit step function and $y[-1] = 0$. Answer the following:
- (a) Use MATLAB to generate and plot $y[n]$ for $0 \leq n \leq 100$ with $a = 0.5$. What is the value of $y[10]$? Do you think that the system is stable? Why?
- (b) Use MATLAB to generate and plot $y[n]$ for $0 \leq n \leq 100$ with $a = 2$. What is the value of $y[10]$? Do you think that the system is stable? Why?

References:

- [1] S. Attaway, *MATLAB: A Practical Introduction to Programming and Problem Solving*, 5th Edition, Butterworth-Heinemann, 2019
- [2] A. Gilat, *MATLAB: An Introduction with Applications*, 5th Edition, John Wiley & Sons, 2015
- [3] <https://help.eng.cam.ac.uk/software/matlab/>
- [4] <https://www.mathworks.com/help/matlab/index.html>