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西交利物浦大学

EEE411 Advanced Signal Processing

Assignment I: Signals and Spectra with Matlab

Due on Sunday October 27th 2019, 23:59

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Regulations:

- This is an individual assignment accounting for 15% of the overall assessment for this module. Each student should submit the report **(.doc / .docx / .pdf)** directly on ICE before deadline;
- A coversheet can be created in your own choice but the following information must be included: Your student ID number, full name, email address and name of the module.
- Write a report which should contain a concise description of your reasoning, results and observations to each question. All the formula, derivations, completed Matlab scripts and functions that are NOT provided on ICE, with original highlighted text format in Matlab editor and output waveforms should be part of your reports. You can find a sample answer on the last two pages of this document.
- Toolbox Functions and GUI Tools are NOT ALLOWED to use.
- You may refer to textbooks and lecture notes to discover approaches to problems, however the report should be your own work. Where you do make use of other references, please cite them in your work and provide a list of references in IEEE style. Students are reminded to refer and adhere to plagiarism policy and regulations set by XJTLU.
- Assignments may be accepted up to 7 days after the deadline has passed; a late penalty of 10% will apply for each day late without an extension being granted. Submissions over 7 days late will not be marked. Emailed submissions will NOT be accepted without exceptional circumstances.

Assignment I: Signals and Spectra with MATLAB

MATLAB is a very convenient programming language for signal processing. In this practical you will learn how to use MATLAB to generate and represent signals in time and frequency domain, and how to plot them. For more information on MATLAB commands or functions, you may use the MATLAB documentation or the MATLAB commands ***help*** and ***doc*** - or one of the many MATLAB tutorials on the internet.

Do the following exercises with MATLAB. Exercises 1–6 are preparing you for Exercises 7 and 8.

Problem 1 (*6 points*)

Complex numbers

(a) For the complex number $x = 1 + j$, compute the real part, the imaginary part, the absolute value and the angle; *(4 points)*

(b) For the complex numbers $\{1, j, -1, -j\}$, compute the real part, the imaginary part, the absolute value and the angle, using vector operations. *(2 points)*

Problem 2 (*9 points*)

Function plots

(a) Plot the function $y = x^2$ for $x \in [0, +2]$; *(3 points)*

(b) Plot the function $y = x^{\frac{1}{2}}$ for $x \in [0, +2]$ in green in the same figure; *(3 points)*

(c) To above plot, add labels for the axes and grid lines. Add further title and a legend. *(3 points)*

Problem 3 (*9 points*)

Complex exponential function

(a) Plot the function $y = \sin(2\pi t)$ for $t \in [0, 2.5]$; *(2 points)*

(b) Consider the function $x = e^{j2\pi t}$ for $t \in [0, 2.5]$. For this function, plot the real part, the imaginary part, the absolute value and the angle in four different subplots in the same figure; *(4 points)*

(c) Make a 3D plot of the function $x = e^{j2\pi t}$ for $t \in [0, 2.5]$. Add labels for the three axes. (And rotate the figure with the mouse.) *(3 points)*

Problem 4 (*12 points*)

Plots and sampling period

Consider the signal $x(t) = \sin(2\pi f_0 t)$ for $t \in [0, 2T_0], T_0 = 1/f_0$ and $f_0 = 10^3$ Hz.

(a) Use the sampling period of $T_s = T_0/10$ (*i.e.,* 10 sample points per T_0 seconds) and plot the signal; *(3 points)*

(b) Use the sampling period $T_s = T_0/20$ and plot the signal in the same figure (in a different colour); *(3 points)*

(c) Use the sampling period $T_s = T_0/4$ and plot the signal in the same figure (in a different colour); *(3 points)*

(d) Interpret the results. *(3 points)*

Problem 5 (*9 points*)

The rectangular pulse
Consider the rectangular pulse

$$\texttt{rect}(t) = \begin{cases} 1, & \text{for } |t| \leqslant \frac{1}{2}, \\ 0, & \text{otherwise;} \end{cases}$$

(a) Write a MATLAB function for `rect`(t); *(3 points)*

(b) Plot `rect`(t) for $t \in [-2, 2]$; *(3 points)*

(c) Define the x-axis to go from -3 to $+3$, and the y-axis to go from -2 to $+2$. Label the axes. *(3 points)*

Problem 6 (*9 points*)

The sinc-function
Consider the function

$$\text{sinc}(t) = \frac{\sin \pi t}{\pi t},$$

and use the corresponding MATLAB function in the following.

(a) Plot the signal $s(t) = \text{sinc}(f_0 t)$ for $t \in [-10T_0, 10T_0], f_0 = 1/T_0, T_0 = 2$ s. Use the sampling period $T_s = T_0/10$; *(4 points)*

(b) Turn on the grid lines in the figure; *(2 points)*

(c) Interpret the zeros of $s(t)$. *(3 points)*

Problem 7 (*15 points*)

Manipulations of signals

(a) Plot the signal $x_1(t) = 2 \cdot \sin(2\pi f_1 t)$ with $f_1 = 10$ Hz; *(3 points)*

(b) Plot the signal $x_2(t) = 2 + x_1(t)$; *(3 points)*

(c) Plot the signal $x_3(t) = \sin(2\pi f_3 t)$ with $f_3 = 10 f_1$; *(3 points)*

(d) Plot the signal $x_4(t) = x_1(t) \cdot x_3(t)$; *(3 points)*

(e) Comment your results especially for $x_4(t)$. *(3 points)*

Problem 8 (*31 points*)

Spectra of signals
Use the MATLAB function ***ft.m*** (provided on the ICE) to compute the Fourier transform. (This function is only a user-friendly interface to ***fft.m***.)
Write an m-file to perform steps (a) to (c). This will make it easier for you to do (e), (f), and (g).

(a) Define a sinusoidal signal $x(t)$; *(3 points)*

(b) Compute the Fourier transform $X(f)$ of this signal; *(2 points)*

(c) Use a figure with two subplots, and plot the signal in one subplot and its magnitude spectrum in the other subplot; *(3 points)*

(d) Interpret your results; *(2 points)*

(e) Change the length of the signal $x(t)$ and repeat (b), (c), (d); *(7 points)*

(f) Change the sampling period of the signal $x(t)$ and repeat (b), (c), (d); *(7 points)*

(g) Define a rectangular signal $y(t)$ and repeat (b), (c), (d). *(7 points)*

Sample Question

Use function **cal_roots.m** on ICE to solve the following quadratic equations:

(a) $x^2 + 5x + 6 = 0$,

(b) $x^2 + 4x + 4 = 0$,

(c) $x^2 + 2x + 5 = 0$,

(d) $2x + 5 = 0$.

Sample Solution

For a general quadratic equation $ax^2 + bx + c = 0$, the roots of the equation can be found in the following:

1. $a = 0$, It is not a quadratic equation.
2. $a \neq 0, \Delta = b^2 - 4ac = 0, x = -\dfrac{b}{2a}$.
3. $a \neq 0, \Delta = b^2 - 4ac \neq 0, x = \dfrac{-b \pm \sqrt{\Delta}}{2a}$.

The listing below shows a MATLAB function that was used to solve the given quadratic equations.

Listing 1: MATLAB function **cal_roots.m**

```
function cal_roots(a,b,c)
% cal_roots solves a quadratic function ax^2+bx+c=0
if a==0
    error('a = 0 -- Not a quadratic equation');
% b^2-4*a*c==0
elseif abs(b^2-4*a*c)<1e-10
    x = -b/(2*a)
else
    x1 = (-b+sqrt(b^2-4*a*c))/(2*a)
    x2 = (-b-sqrt(b^2-4*a*c))/(2*a)
end;
```

Below are the MATLAB outputs from Command Window while invoking the function **cal_roots.m**.

```
>> cal_roots(1,5,6)

x1 =

    -2


x2 =

    -3

>> cal_roots(1,4,4)
```

```
x =

    -2

>> cal_roots(1,2,5)

x1 =

  -1.0000 + 2.0000i


x2 =

  -1.0000 - 2.0000i

>> cal_roots(0,2,5)
Error using cal_roots (line 4)
a = 0 -- Not a quadratic equation
```