Course: DSP Lab

Session 2: Discrete Fourier Transform

Dept.: Electrical & Electronics Engineering V1.3

Notes:

a) **Use plot() for analog signal plots and stem() for discrete signal plot.**
b) **Every plot must have labels for X-axis, Y-axis and title.**

1 Objectives/Outcome:

1) To be able to start developing algorithms to convert the mathematical formulations to functions/programs – DFT and IDFT
2) To understand the DFT and interpretations of output for different signal inputs

2 Tasks

2.1 Task1: Develop DFT function

Develop a function $[Xk, fk] = \boldsymbol{directDFT}(\boldsymbol{x},\ \boldsymbol{F_s}, \boldsymbol{N})$ that computes DFT based on direct computation:

$$[Xk, fk] = \sum_{n=0}^{N-1} x(n)\, W_N^{nk}$$

Function parameters in the same order:

- x: Input samples
- F_s: Sampling frequency
- N : Number of samples on input

Return from function:

- Xk: a complex vector corresponding to the DTFT sampled at the points in $\omega = 2\pi/N$.
- fk: Frequency vector that comprises of frequency bins 0, $\boldsymbol{F_s/N}$**,** $\boldsymbol{2F_s/N}$**,** $\boldsymbol{3F_s/N}$ **.......** $\boldsymbol{(N-1)F_s/N}$

Similarly, one must be able develop $\boldsymbol{MydirectDFT}(\boldsymbol{x},\ \boldsymbol{F_s})$ with the input N not passed. In this case the length of input x is taken as N. You can make use of $\boldsymbol{directDFT}(\boldsymbol{x},\ \boldsymbol{F_s}, \boldsymbol{N})$ internally

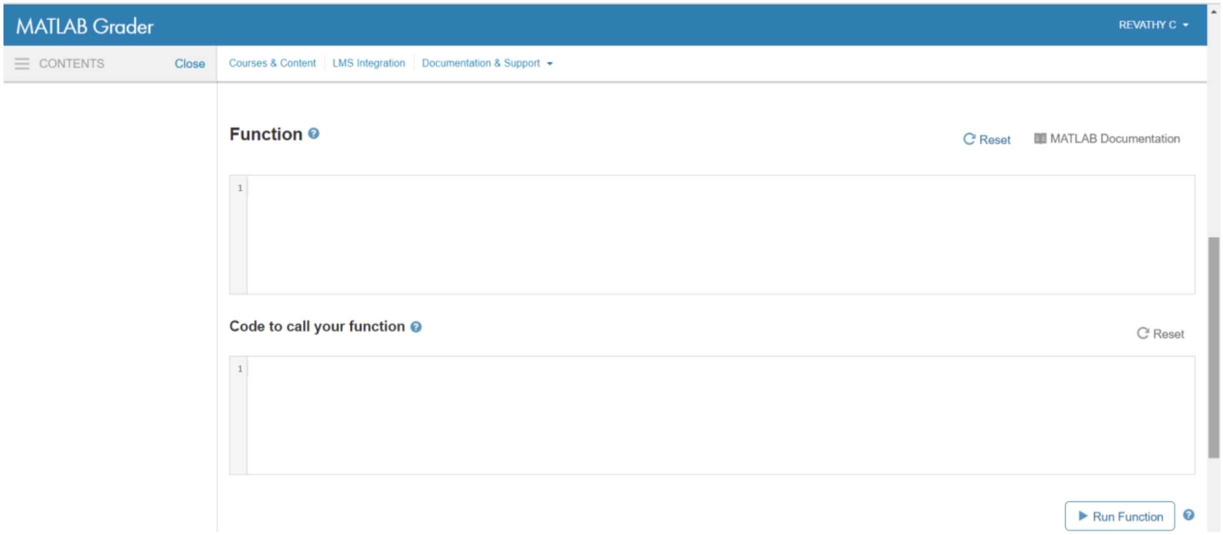
Test the function ***MydirectDFT()*** with the following input cases and plot $X(k)$ vs fk for the following CT signal being discretised (N is not passed as a parameter):

1) $x_1(t) = \mathrm{A}_1 \cos 2\pi F_1 t$ with $A_1 = 0.7, F_1 = 50Hz,\quad F_s = 1000\ Hz, N = 1500$
2) $x_2(t) = \mathrm{A}_2 \cos 2\pi F_2 t$ with $A_2 = 2.7, F_2 = 120Hz,\ F_s = 1000\ Hz, N = 1500$
3) $y(t) = (\mathrm{A}_1 \cos 2\pi F_1 t\ +\ \mathrm{A}_2 \cos 2\pi F_2 t)$ with $F_s = 1000\ Hz,\ N = 1500$

Take a plot of magnitude and list out your observations on the output. Substantiate the outputs if they are correct.

CRITERIA

1. Develop a function **“MydirectDFT”** to compute DFT
2. Write the code for function in “function” section



3. Test cases should be coded in “code to call your function” section (as shown in the figure above)
4. For Test Case 1 use **“xk1, fk1”** for evaluation
5. For Test Case 2 use **“xk2, fk2”** for evaluation
6. For Test Case 3 use **“xk, fk”** for evaluation

2.2 Task2: Test DFT with varied F_s and N

Test the function with parameter N passed different f_s and plot $X(k)$ for the following CT signal being discretised:

$y(t) = (\mathrm{A}_1 \cos 2\pi F_1 t \ + \ \mathrm{A}_2 \cos 2\pi F_2 t), \ \ A_1 = 0.7, F_1 = 50Hz, A_2 = 2.7, F_2 = 120Hz$

1) $F_s = 500\ Hz,\ N = 1500$
2) $F_s = 500\ Hz,\ N = 500$
3) $F_s = 120\ Hz,\ N = 500$
4) $F_s = 60\ Hz,\ N = 500$
5) Fs = 60Hz 450 samples, but N is passed 500 (The function called is expected to fill in 0s for non-existing sequences of n)

List out your observations on the output. Substantiate the outputs if they are correct.

Criteria

1. Develop a function **“directDFT”** to compute DFT
2. For Test Case 1 use **“xk1, fk1”** for evaluation

3. For Test Case 2 use **“xk2, fk2”** for evaluation
4. For Test Case 3 use **“xk3, fk3”** for evaluation
5. For Test Case 4 use **“xk4, fk4”** for evaluation

2.3 Task3: Develop IDFT

Add the IDFT functionality very much on same lines as DFT. Develop a function $\boldsymbol{directIDFT}(\boldsymbol{Xk},\ \boldsymbol{N})$ that computes DFT based on direct computation:

$$x(n) = (\frac{1}{N})\ \sum_{k=0}^{N-1} X(k)\ W_N^{-nk}$$

Function parameters in the same order:

- Xk: FFT input (Can be complex input)
- N : Number of points

Return from function:

- x: a complex vector input sequence extracted

Similarly, one must be able to use $\boldsymbol{directIDFT}(\boldsymbol{X})$ with the input N not passed. In this case the length of input X is taken as N.

1) Make use of the functions $directDFT()$ to check the IDFT is correct with the help of $directIDFT()$.
   $xn = [1\ 2\ 3\ 4\ 5\ 6]$
   $Xk\ =\ directDFT([1\ 2\ 3\ 4\ 5\ 6], 6)$
   $yn\ =\ directIDFT(Xk, 6)$
   Test whether xn and yn are equal

2) Make use of the functions $directDFT()$ to check the IDFT is correct with the help of $directIDFT()$.
   Generate 128 samples of $xn1 = \cos 2\pi(50)n$
   $Xk\ =\ directDFT(xn1)$
   $yn1\ =\ directIDFT(Xk)$
   Test whether $xn1$ and $yn1$ are equal

Criteria

1. For Test Code 1 use **“xn, yn”** for evaluation
2. For Test Code 2 use **“xn1, yn1”** for evaluation
3. Must display whether xn and yn are equal or not.

2.4 Task4: Finding DFT for your voice recorded signal

Record your voice on your mobile in WAV or MP3 format. Determine the DFT using the function, plot and interpret the results.