Signals Systems and Transforms
EEET-332
Lab 11

For each section using MATLAB:

1) Create a new *.m (or *.mlx) file and call init() in the first line. Save it. Remember, no spaces in the file name!
2) Copy last lab's init.m, make_plot.m (or *.mlx) functions to the same directory.

Prelab: There is no prelab.

Section 1. DTMF generation

Interpreting a Fourier spectrum is a skill that is useful for several purposes, for instance, to determine the cutoff frequencies for a filter used for noise reduction. In this lab, you will analyze the Fourier spectrum to identify the frequency of the signal components or harmonics.

We will focus on Dual Tone Muti-Frequency signals, which are the audio tones generated when you dial a number on a landline telephone or press a number key of a landline or cellular phone to interact with automated call center services.

Watch the following video that explains the principles of DTMF:
https://www.youtube.com/watch?v=y5C244KrQpE

In addition, to call center applications, DTMF can also be useful for controlling remote devices. Watch the following videos:
https://www.youtube.com/watch?v=gp7h1HaImNQ
https://www.youtube.com/watch?v=pCC0NA9K4rU

In this lab, you will create and play DTMF signals.
The following table displays the DTMF frequencies for each key. For instance, when the '1' key is pressed, the DTMF generated will be the sum of two cosine signals of frequencies f_1 = 697 Hz and f_2 =1209 Hz.

$$y = \cos(2\pi f_1 t) + \cos(2\pi f_2 t) \qquad \text{Equation 1.}$$

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	1209 Hz	1336 Hz	1477 Hz	1633 Hz
697 Hz	1	2	3	A
770 Hz	4	5	6	B
852 Hz	7	8	9	C
941 Hz	*	0	#	D

Create a new script with the code below

```
init();
N = 10000; %number of samples in time and freq domain
T = 0.5; % Signal period
Ts = T/N; %sample period
Fs = 1/Ts; %Sample rate
t=0:Ts:T-Ts;
ind=0:(N-1);

% DTMF for '1'
f1 = 697;
f2 = 1209;
y1 = cos (2*pi*f1*t) + cos(2*pi*f2*t);
make_plot(t(1:500),y1(1:500),'key = 1','t','amplitude')
% compute cm
cm_key1 = fft(y1)/N;
make_plot(ind,abs(cm_key1),'Spectrum','index','magnitude')
```

Run the script. The following plots will be displayed.

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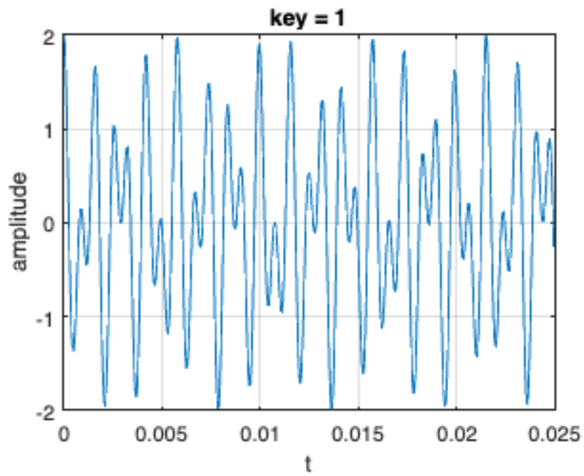

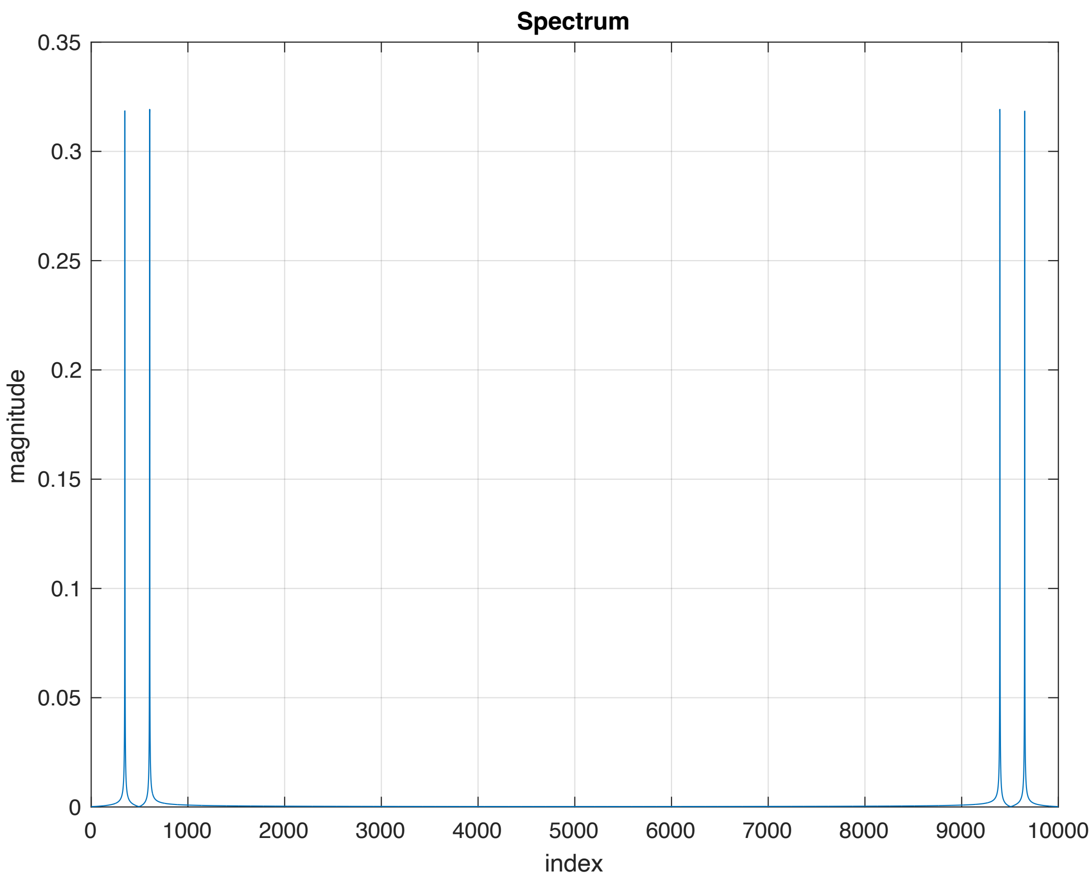

The 4 vertical lines in the spectrum indicate that there are two cosine components in the DTMF signal. This is two lines for each cosine signal. The indexes of such spectral lines are related to the frequencies of the cosine waves. However, it is more convenient to set the x_axis units to Hz.

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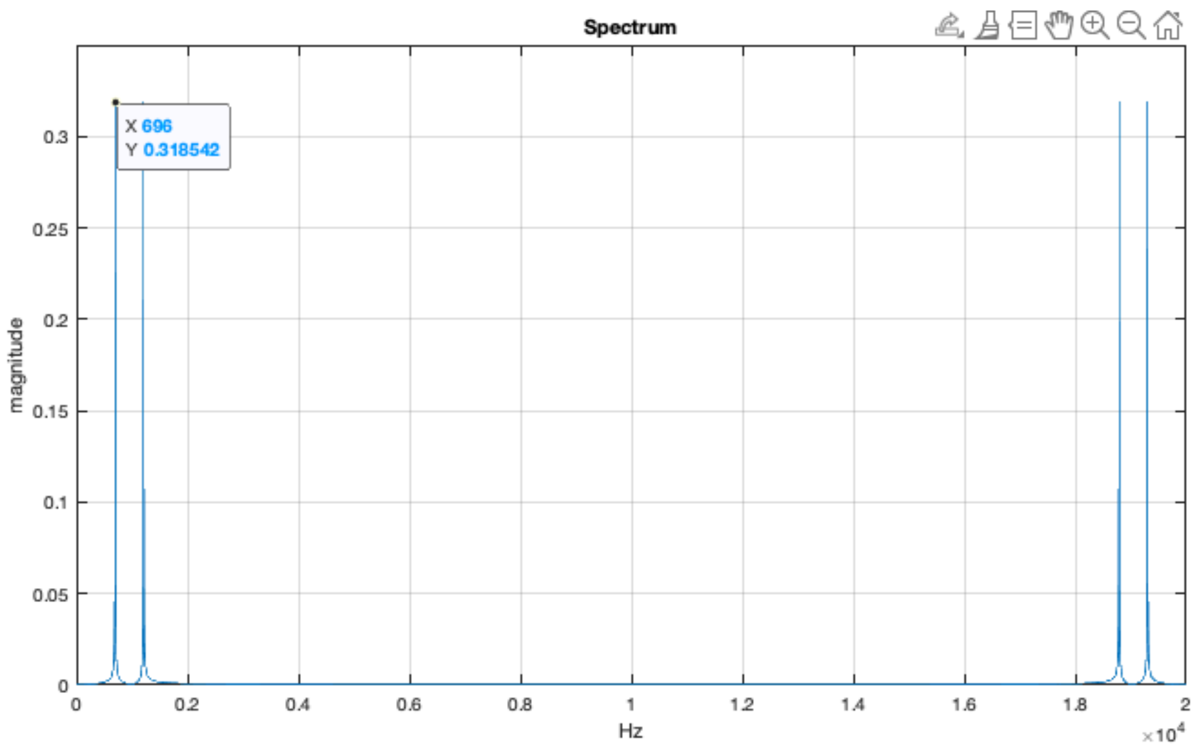
Add the following lines to the script:

```
f_hz = (ind)/N*Fs;   % x-axis
make_plot(f_hz,abs(cm_key1),'Spectrum','Hz','magnitude')
```

In the following plot, f_1 is identified. Note that the value of the spectral line frequency (696 Hz) is close to 697 Hz due to the spectrum resolution.



Modify the script and plot the spectrum for ‘5’ and ‘8’. Identify f_1 and f_2 in each plot and get a sign-off.

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Section 2. Playing DTMF tones

Complete the following code and create a new script

```
init();
N = 10000; %number of samples in time and freq domain
T = 0.5; % Signal period
Ts = T/N; %sample period
Fs = 1/Ts; %Sample rate
t=0:Ts:T-Ts;

% DTMF for '1'
f1 = 697;
f2 = 1209;
y1 = cos (2*pi*f1*t) + cos(2*pi*f2*t);
% DTMF for '2'
f1 =______;
f2 = ______;
y2 = cos (2*pi*f1*t) + cos(2*pi*f2*t);
% DTMF for '3'
f1 = _____;
f2 = ______;
y3 = cos (2*pi*f1*t) + cos(2*pi*f2*t);
% DTMF for '4'
f1 = _____;
f2 = _____;
y4 = cos (2*pi*f1*t) + cos(2*pi*f2*t);

sound(y1,Fs);
pause(0.6);
sound(y2,Fs);
pause(0.6);
sound(y3,Fs);
pause(0.6);
sound(y4,Fs);
```

Record the sound generated when running the script. Submit the recording file or a link to the recording. Hint: You can use your smartphone to record the DTMF.

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Section 3. DTMF detection

DTMF frequencies can be easily identified in the spectrum plot. Therefore, we can build a DTMF detector by identifying the frequencies of the first two largest peaks displayed in the spectrum.

Create the following function in a separate file; name it findpeaks.m

```
function [freqs] = findpeaks(y)
%
N = 10000; %number of samples in time and freq domain
T = 0.5; % Signal period
Ts = T/N; %sample period
Fs = 1/Ts; %Sample rate
t=0:Ts:T-Ts;

% % compute cm
cm= fft(y)/N;
% Find peaks
[a,indexes] =maxk(abs(cm),4); %detect the 4 largest spectral lines
%Convert indexes to Hz
freqs = (indexes-1)/N*Fs;
freqs=sort(freqs)  % sort the frequencies
max_freq_error = 3; % Maximum error due to the spectrum resolution

% Check if a '1' was received
if (abs(freqs(1)-697) < max_freq_error && abs(freqs(2)-1209)<max_freq_error)
    disp('key pressed:1')
end

% Check if a '5' was received
%if (abs(__________) < max_freq_error && abs(_________) < max_freq_error  )
%    disp('key pressed:5')
%end

% Check if a '9' was received
%if (abs(___________) < max_freq_error && abs(__________) < max_freq_error  )
%    disp('key pressed:9')
%end
```

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Create a new script with the following code

```
init();
N = 10000; %number of samples in time and freq domain
T = 0.5; % Signal period
Ts = T/N; %sample period
Fs = 1/Ts; %Sample rate
t=0:Ts:T-Ts;

% DTMF for '1'
f1 = 697;
f2 = 1209;
y1 = cos (2*pi*f1*t) + cos(2*pi*f2*t);
% DTMF for '5'
f1 =770;
f2 =1336;
y5 = cos (2*pi*f1*t) + cos(2*pi*f2*t);
% DTMF for '9'
f1 = 852;
f2 = 1477;
y9 = cos (2*pi*f1*t) + cos(2*pi*f2*t);

findpeaks(y1);
%findpeaks(y5);
%findpeaks(y9);
```

Run the script, the output should be as follows

```
freqs = 1×4
         696        1210        18790        19304

key pressed:1
```

Uncomment and complete the code of findpeaks.m function where ‘5’ and ‘9’ are identified.

Uncomment the last two lines in the script.

```
findpeaks(y1);
findpeaks(y5);
findpeaks(y9);
```

Run the script and **submit a screenshot of the output showing the freq vectors and the detection of 1, 5, and 9.**

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Report:

Create your own cover page.

Submit your cover page, the requested prints (sections 2 and 3), the recording file or a link to the recording, and this sign-off sheet.

Sign-offs

Name ________________________

Section 1: ‘5’ and ‘8’ plots

	/ /
Signature	Date