

CSx25: Digital Signal Processing NCS224: Signals and Systems

# **Dual-Tone Multi-Frequency (DTMF) Decoder**

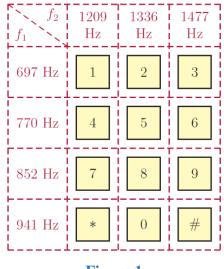
In this project, the concept of *dual-tone multi-frequency* (*DTMF*) signaling will be explored. As the name implies, DTMF signals are mixtures of two sinusoids at distinct frequencies. They are used in communications over analog telephone lines.

A particular version of DTMF signaling is utilized in dialing a number with push-button telephone handsets, a scheme known as touch-tone dialing. When the caller dials a number, the DTMF generator produces a dual-tone signal for each digit dialed.

The synthesized signal is in the form

$$x(t) = \sin(2\pi f_1 t) + \sin(2\pi f_2 t), \qquad 0 \le t \le T_{digit}$$

Frequency assignments for the digits on a telephone keypad are shown in Fig. 1.





The goal of this project is to develop a DTMF synthesizer function using MATLAB.

**a.** For exploratory data analysis, **write** a MATLAB script to accomplish the following:

**Express** the signal  $x(t) = \sin(2\pi f_1 t) + \sin(2\pi f_2 t)$  through the use of a MATLAB anonymous function with  $f_1 = 852$  Hz and  $f_2 = 1477$  Hz.

**Compute** the signal in the time interval  $0 \le t \le 0.2$  with a time increment of  $\Delta t = 1/8000$  s.

**Play back** the resulting sound *x*(*t*) using the **sound** function of MATLAB.

If the signal was computed properly, you should hear a clean short tone.

**Graph** the resulting signal x(t) using the plot function.

**Repeat** the same experiment with different frequencies and different time increments based on Fig. 1. You should hear different short tones.



b. Develop a function named ss\_dtmf1 to produce the signal for one digit. The syntax of the function should be

$$x = ss_dtmf1(n, t)$$

The first argument "n" is the digit for which the DTMF signal is to be generated.

Let values n = 0 through n = 9 represent the corresponding keys on the keypad.

Map the remaining two keys "\*" and "#" to values n = 10 and n = 11 respectively.

Finally, the value n = 12 should represent a pause, that is, a <u>silent period</u> ( $f_1 = 0, f_2 = 0$ ).

The vector "t" contains the time instants at which the DTMF signal x(t) is evaluated and returned in vector "x".

c. **Develop** a function named ss\_dtmf with the syntax

x = ss\_dtmf(number, delta, nd, np)

The arguments for the function **ss\_dtmf** are defined as follows:

number: The phone number to be dialed, entered as a vector.

For example, to dial the number 5551212, the vector "number" would be entered as

delta: The time increment  $\Delta t$  to be used in computing the amplitudes of the DTMF signal. nd: Parameter to control the duration of the DTMF signal for each digit.

The duration of each digit should be

$$T_{digit} = n_d \Delta t$$

np: Parameter to control the duration of pause between consecutive digits. The duration of pause should be

$$T_{pause} = n_p \Delta t$$

The function  $ss_dtmf$  should use the function  $ss_dtmf1$  to produce the signals for each digit (and the pauses between digits) and append them together to create the signal x(t).

**d.** Write a script to test the function ss\_dtmf with the number 5551212.

Use a time increment of 125 microseconds (delta = 1/8000) corresponding to 8000 values per second. The duration of each digit should be 200 milliseconds (nd = 1600) with 80 millisecond pauses between digits (np = 640).

**Play back** the resulting signal x(t) using the sound function.

Also, **graph** the resulting signal x(t) using the **plot** function.



e. Write a MATLAB script to accomplish the following tasks: Express the following three signals through the use of MATLAB anonymous functions with  $f_1 = 852$  Hz and  $f_2 = 1477$  Hz.

$$x_{1}(t) = \sin(2\pi f_{1}t)$$
  

$$x_{2}(t) = \sin(2\pi f_{2}t)$$
  

$$x(t) = \sin(2\pi f_{1}t) + \sin(2\pi f_{2}t)$$

**Compute** each signal for n = 1600 samples with a sampling frequency of  $f_s = 8000$ . You can compute the time vector (t) using the following MATLAB code:

fs = 8000;

$$t = (0:(n-1)) / fs;$$

**Listen** to each resulting signal **separately** using the **sound** function of MATLAB. **Graph** the resulting signals  $x_1(t)$ ,  $x_2(t)$ , x(t) in **one graph** using the **subplot** function.

The Fourier transform of the sine function is

$$\mathcal{F}\{\sin(2\pi f_0 t)\} = \frac{1}{2j} \left[\delta(f - f_0) - \delta(f + f_0)\right]$$

**Compute** the discrete Fourier transform (DFT) of each signal using the function fft, then **shift** the zero-frequency component to center of spectrum using the function fftshift. **Graph** the **magnitude of the DFT** of each signal in **one graph** using the subplot function. You can compute the frequency vector (f) using the following MATLAB code:

f = (-n/2:n/2-1) \* (fs/n);

## Report

Deliver a report, show the main function, and discusses your implementation.



### **MATLAB Useful References**

You may need the following MATLAB functions and references.

- plot
- subplot
- sound
- cat
- fft: <u>How to Do FFT in MATLAB</u>
- fftshift
- Plot FFT using MATLAB

#### Example

How to take FFT in Matlab | FFT Matlab Plot Frequency | FFT Matlab Easy Tutorial - YouTube

#### Bonus

**Develop** a GUI-based MATLAB program to model the operation of the DTMF decoder. Your program should include an interactive telephone keypad are shown in Fig. 1.

> GOOD LUCK, Eng. Abdallah El Ghamry Dr. Ahmed Shalaby