PROJECT 3: DUAL-TONE MULTI-FREQUENCY SIGNAL DETECTION

due December 21 – 9:00 AM

Introduction:

In this project, you will use Arduino Uno to transmit, receive and detect Dual-Tone Multi-Frequency (DTMF) signals, used in classic telephone signaling.

The DTMF system is used for encoding and decoding a total of 16 symbols (10 digits, 4 letters and 2 signs) with 8 distinct sinusoidal tones (4 low-frequency and 4 high-frequency). Each symbol is represented by a composition of 2 sinusoidal tones (1 low-frequency and 1 high-frequency). See the figure below for the symbol-to-dual tone mapping. For example, the number "2" is represented by a DTMF signal, which is the superposition of two sinusoidal tones at 697 Hz and 1336 Hz.

	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

Figure 1 – DTMF Mapping Table

For more info, refer to: https://en.wikipedia.org/wiki/Dual-tone_multi-frequency_signaling

SYSTEM DESIGN AND DESIDERATA:

You are expected to design a system, which

i) generates DTMF signals according to Figure 1,
ii) transmits the generated DTMF signal through the Arduino board,
iii) detects the received signal (Arduino output) by digital filtering.

I) DTMF Signal Generation

You can generate a DTMF signal using some simple tools, which can be found at

PC: http://onlinetonegenerator.com/dtmf.html

Android app example: https://play.google.com/store/apps/details?id=com.amknott.ToneGen

Then, you can use a standard audio jack connected to a PC or smartphone, to feed the DTMF signals to your Arduino via the "Analog Input".

II) DTMF Signal Reception

Arduino will sample and quantize the analog signal and convert it to the digital domain. This digital signal can be acquired through the USB connection between the PC and the Arduino board. For this purpose, you must design an Arduino setup in order to properly receive the analog signal from the PC and feed it back to the PC's USB port. For this, you might need to use resistors, capacitors, etc.

Hint: If the transmitted signal strength is too weak, you may need to use an amplifier before feeding it into Arduino analog input.

III) DTMF Signal Detection

The obtained digital signal is to be detected by digital processing techniques in MATLAB. Therefore, you should write a MATLAB program which consists of

a) an input function, to get the digital signal outputted by the Arduino board,
b) a processor function, to decode the DTMF signal and
c) an output function, to display the detected symbol on the command window.
d) a main script.

IMPORTANT: This main goal of this project is to allow the students to experiment with digital filtering techniques. In this regard, while simply taking the DFT of the signal, and detecting the peaks would also accomplish our goal, this will not be an acceptable method for our project. The same goes for Goertzel algorithm, which is just a more efficient way of calculating the DFT for a list of frequencies.

The design of the filtering and detection techniques that you will use is left to you. However, at the very least you will need to use digital low/high/band pass filtering to differentiate the DTMF signals.

Digital filtering involves several design choices:

a) Should you use an FIR or an IIR filter?
b) What should be the coefficients of the filter?
c) What should you do with the filter outputs?

Hint: You can use the energy levels at the output of a set of band-pass filters and make threshold-based decisions. Then of course the threshold selection would be another design parameter.

PERFORMANCE REQUIREMENTS

1) Your system has to be *accurate and stable*. That is, it has to give correct outputs for all 16 DTMF symbols at all times. **In this regard, the following system is unacceptable:**
   Input: 12*22345 ➔ Output: 12*1234#

2) You need to detect the DTMF signals within *an acceptable time frame*. For example, the industry standard is 40 milliseconds. That is, the systems can detect DTMF signals as short as 40 ms. Therefore, there must not be any perceivable delay between generating the DTMF signal and observing the output in the command window.

3) Your system has to give *exactly one output for each press*. Meaning, the command window must show the output only and exactly once, when a symbol is pressed only once at the DTMF generator. **In this regard, the following system is unacceptable:**
   Input: Press 1 for 2 seconds ➔ Output: 1111111

4) You must demonstrate that your system satisfies the given performance requirements.

REPORTS

Your project report should consist of the following parts.

1. Introduction: First, describe the objective clearly. Then, explain how you achieve the objective with your design. You should enumerate and briefly explain the building blocks of your design. Keep this part short and simple but be precise.
2. System Design: In this part, you must explain how you generate, transmit, receive and detect a DTMF signal.
    a. Include a photo of your Arduino setup, and label the connections.
    b. Explain your entire MATLAB program in detail in this part. Show us how you implemented your DTMF system, by explaining step-by-step each line or block of codes. Make sure your code is understandable.
    c. Explain your design choices (why you used certain techniques over others) and how you selected various parameters (filter coefficients, thresholds, etc.) in detail.
    d. Plot the frequency and magnitude response of one of the filters that you designed and insert it to the report.
3. Results and Conclusion: In this part, you must talk about your results and conclude your report.
    a. Does your design work properly? Comment on how accurate your DTMF system is.
    b. What can you do to improve it more?
    c. Comment on the design difficulties that you have encountered and how you solved them.

DEMONSTRATIONS

The demonstrations will be held between December 21-23. Further information is to be announced.