Lab 1 - DTMF Measurement

Note: This lab will be held in SW1-3575 instead of SW1-3575.

Introduction

In this lab you will examine the spectrum of a Dual-Tone Multi-Frequency (DTMF) signal and decode a DTMF digit by examining its spectrum.

DTMF Signals

DTMF (Dual Tone Multi-Frequency) is a signalling method used over telephone channels for dialing and other purposes. You may know it by the former trademark "Touch-Tone".

A DTMF signal consist of two sine waves, one chosen from one of four low-frequency tones and one chosen from one of four high-frequency tones. The diagram below (from Wikipedia) shows the pairs of tones used to generate each digit.

	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

For example, the when you press the '1' button on a phone keypad a signal consisting of a sine wave at 697 Hz plus one at 1209 Hz is generated.

Procedure

Download the `DTMFSamples.zip` file from the course web site (under Content->Labs). The instructor will tell you which signal you are to measure. Extract the appropriate waveform and open it with the Audacity audio editor. Run Transport-> Loop Play to play the waveform through the PC's audio output continuously.

Plug the audio cable into the speaker output on the front of the PC and connect the 'scope probes to the wires at end of the cable (the yellow wire is ground, orange and violet are the audio signal):
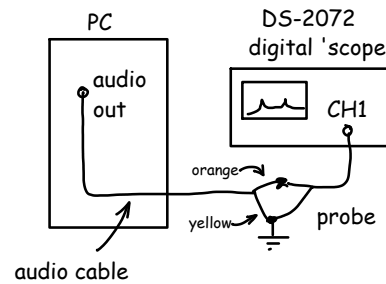
Display the signal on Channel 1. Select AC coupling and set the vertical gain to get the largest signal without clipping. Set the horizontal scale to get several cycles of the waveform.

Select the Measurement menu, enable frequency measurement and record the results.

Change the horizontal scale control to 10 ms per division. Press the Math menu button and select FFT operation with Channel 1 as the source. The screen should now split into two parts with the time-domain waveform shown on top and the frequency-domain (the spectrum) shown on the bottom (see Figure 1).

The Math menu will now let you adjust the vertical gain (dB/division) and vertical offset (dBV). When you are in the FFT mode the Horizontal scale control sets the frequency scale (Hz/division) rather than sampling rate and the Horizontal position sets the center frequency. These values will be shown on the screen.

If you need to re-adjust the sampling rate, gain or DC coupling you can select the Channel 1 menu.

You should now see the two tones as peaks in the spectrum. You may need to reduce the horizontal and vertical gains (in the Math menu) to find the signals. Adjust the controls to "zoom in" on the signal to get good horizontal and vertical resolution.

Enable the cursor menu and select manual mode, X type and set the source to Math. This will enable you to place cursors on the two signal peaks so you can measure the tone frequencies. Adjust the two cursors to measure: (a) the width of the peak about each tone, and (b) the center frequencies of the tones. The width of the peak can be measured between the -3dB points or to the first "nulls" (specify which one
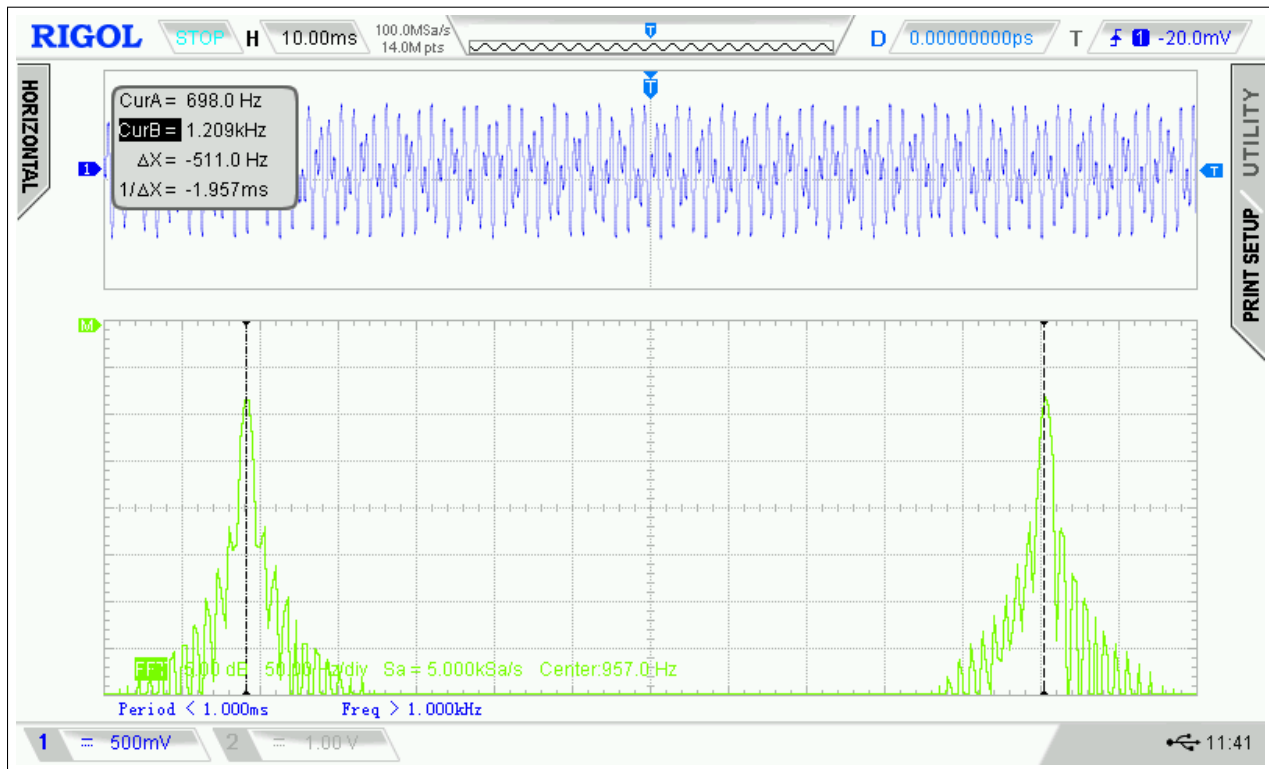
Figure 1: Screen capture showing spectrum of DTMF signal and cursors at tone frequencies.

you measured).

Capture a screen shot to your USB drive showing your tone frequency measurements. It should look something like the one in Figure 1. The scale is difficult to see in this example because it overlaps the signal but it shows the scale is 5dB per division vertically and 50.00 Hz/div horizontally with a center frequency of 957.0Hz. The cursor information box shows the two cursor frequencies and their frequency spacing.

Change the vertical gain to 1 dB/division, the cursor type to Y and measure the difference in the tone levels.

Change the horizontal scale to 2 ms/division and display only one tone. Re-measure the width of the peak around each tone.

DFT Frequency Resolution

The 'scope computes the spectrum using a DFT (Discrete Fourier Transform). An FFT (Fast Fourier Transform) is simply an efficient algorithm for computing the DFT. The frequency resolution of an FFT is inversely proportional to the duration (length in time) of the signal being analyzed. The portion of the signal analyzed by the 'scope in the lab is the portion that is displayed. This duration is given by the horizontal scale (ms/division) multiplied by the number of divisions (14 in most cases). In Figure 1, the waveform duration is 140 ms (14 divisions $\times$ 10 $\frac{\text{ms}}{\text{division}}$ = 140 ms). We would expect the frequency resolution to be about $\frac{1}{0.140} \approx 7$ Hz.

Pre-Lab Assignment

Answer the following questions:

What is the minimum duration of a DTMF digit? If the frequency resolution is inversely proportional to the measurement duration, what frequency resolution could be obtained when measuring the frequency of a DTMF tone? How does this compare to the spacing between tones?

What is longest period of any DTMF tone? How many cycles of this tone are there during the minimum digit duration?

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Submit your pre-lab report to the dropbox on the course web site.

Report

Submit a lab report to the dropbox on the course web site containing the following:

- the course name and number, lab number and title, your name and BCIT ID number, and the date the report was written (you may want to save this as a template to re-use in future labs).

- the of the name waveform file you were assigned (e.g. `a.wav`)

- a brief explanation of why the frequency measurement function did or did not work

- your captured screen shot showing the spectrum, cursors and frequencies

- the frequencies of the tones you measured

- the corresponding DTMF digit

- the measured width of the peaks in the spectrum (two measurements)

- the theoretical approximate frequency resolution (inverse of the displayed waveform duration) in each case

- the difference in the tone amplitudes (in dB)