

Lab 6 - Signal Spectrum Measurement

Introduction

In this lab you will examine the spectrum of a signal using a digital oscilloscope that has a frequency analysis function.

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.

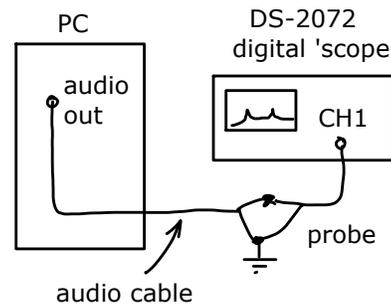
	1209 Hz	1336 Hz	1477 Hz	1633 Hz
697 Hz	1	2	3	A
770 Hz	4	5	6	B
852 Hz	7	8	9	C
941 Hz	*	0	#	D

For example, the when you press the ‘1’ button on a phone keypad a signal consisting of a sine wave at 697 Hz pus 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 other end of the cable (yellow wire is ground):



Display the signal on Channel 1. Select AC coupling and set the vertical gain to get the largest signal without clipping and the horizontal scale to get several cycles of the waveform.

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

Set the horizontal scale control for 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.

The Math menu will now let you adjust the vertical gain (dB/division) and vertical offset (dBV). When you are in the Math menu the Horizontal scale control now 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.

Capture a screen shot showing your tone frequency

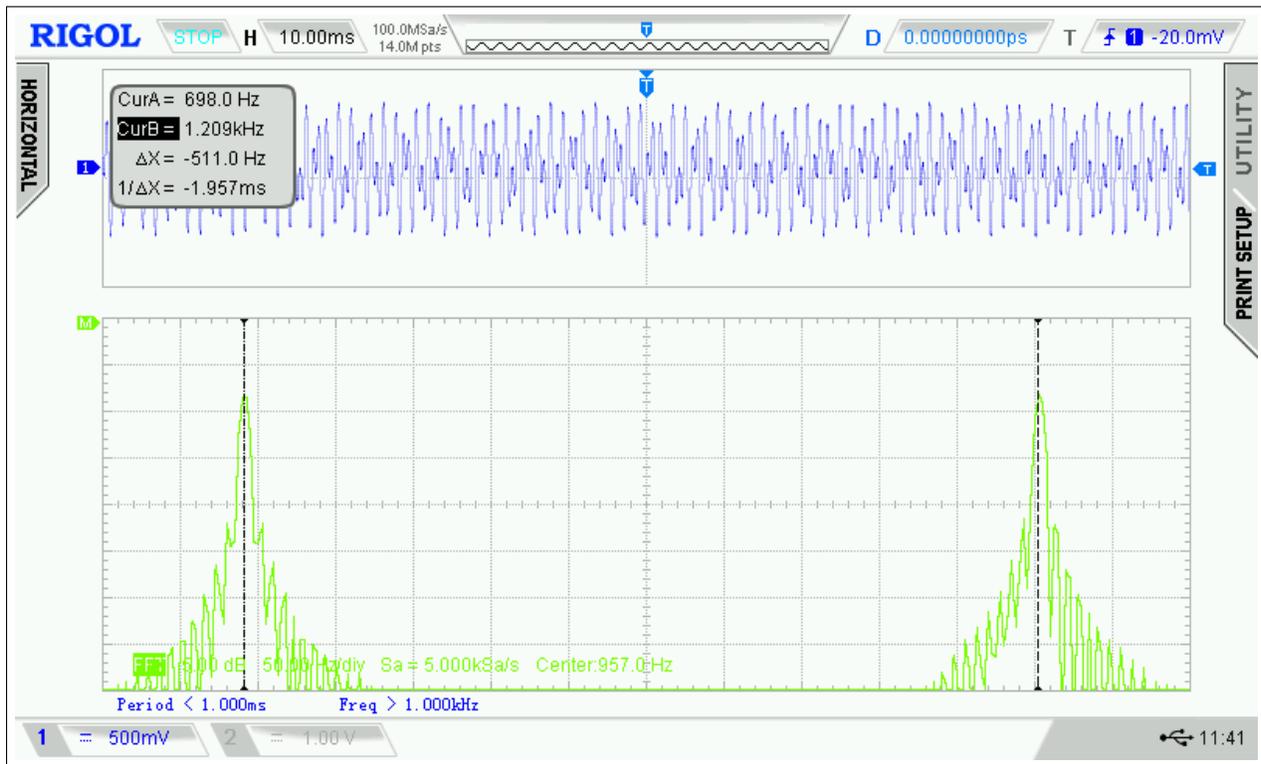


Figure 1: Screen capture showing spectrum of DTMF signal and cursors at tone frequencies.

measurements. It should look something like the one in Figure 1.

DFT Frequency Resolution

The 'scope computes the spectrum using a DFT (Discrete Fourier Transform). The DFT is efficiently computed by the FFT (Fast Fourier Transform) algorithm. 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 (16 in most cases).

Report

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

- the identification information asked for in previous labs
- the name of the 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
- the approximate frequency resolution (inverse of the displayed waveform duration)
- the difference in the tone amplitudes (in dB)