

Applied signal processing

Lab 2, February-2009

In this lab, we will identify the numbers dialed in a touch-tone telephone system.

A touch-tone telephone system is using the sum of two sine waves tones to represent the done dialed, called Dual-Tone Multi Frequency (DTMF). The tones are the following:

	1209 Hz	1336 Hz	1477 Hz	1633 Hz
		ABC	DEF	
697 Hz	1	2	3	A
	GHI	JKL	MNO	
770 Hz	4	5	6	B
	PRS	TUV	WXY	
852 Hz	7	8	9	C
		oper		
941 Hz	*	0	#	D

Hence, a the digit “6” is represented by the sum of one 770 Hz sine wave and one 1477 Hz sine wave.

Producing DTMF can easily be done by applying two digital resonators, corresponding to the one done in lab 1.

Identifying DTMF is a little more tricky. In general, a (Discrete) Fourier analysis can be applied, normally a Fast Fourier Transform (FFT). However, for this special case a algorithm called the *Goertzel Algorithm* is more efficient, as we only need a 8 of the DFT coefficients.

The Goertzel Algorithm computes the k -th DFT coefficient of the input signal $x[n]$ using a second-order filter:

$$\begin{aligned}q_k[n] &= x[n] + 2 \cos \omega_k q_k[n-1] - q_k[n-2] \\y_k[n] &= q_k[n] - q_k[n-1] e^{-j\omega_k}\end{aligned}\tag{1}$$

where $q_k[-2] = q_k[-1] = 0$. The k th DFT coefficient is produced after the filter has processed N samples: $X[k] = y_k[N]$. The DFT (normalized) frequencies ω_k are evenly spaced $\omega_k = 2\pi k/N$. Telephone systems commonly use 8000 Hz sampling frequency. Hence, for a 8000 Hz sampling frequency f_s , given block length $N = 205$, the 770 Hz signal correspond to $k = 20$.

Why use $N = 205$? The minimum duration of a DTMF tone should according to the specifications be 40 ms. Using 8 kHz, this corresponds to 200 samples. In order to match with center frequencies of the DFT's bins, $N = 205$ has commonly been used. Next good choice is $N = 299$. When using 48 kHz sampling frequency, the number of samples needed is of course increased, as 40 ms corresponds to 1200 samples. Now $N = 1232$ is a good choice (or $N = 1792$).

1. Generate DTMF by modifying the digital resonator code from last time.
2. Build a system that identifies the digit dialed. Use the attached telephone system (POTS, Plain Old Telephone System) according to the guidelines given at the lab.

Note! To use 8000 Hz sampling frequency, you must change the sampling rate using the bsl function `DSK6713_AIC23_setFreq()` (`DSK6713_AIC23_setFreq(hCodec, DSK6713_FREQ_8KHZ)`).