**EEE4114F: DSP Project Report**

**DTMF Decoder**

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# Abstract

Dual-tone Multi-Frequency other wise known as DTMF signals are a standard in telecommunications systems. They correspond to touch tone telephones as well as various keystroke based systems. This is where keystrokes from a keypad are translated to dual tone signals.

Dual-tone Multi-frequency (DTMF) signals are used in touch-tone telephones as well as many other areas such as interactive control, telephone banking, and pager system. As analog telephone lines are converted to digital, researchers became interested in digital DTMF detectors. There are many digital DTMF detecting algorithms, but most of them do not comply with the related International Telecommunications Union (ITU) and Bellcore recommendations or are not suitable for real-time implementation. In this project, my primary aim was to implement the new DTMF algorithm proposed by M. D. Felder, J. M. Mason, and B. L. Evans

# Introduction

Dual-tone multi-frequency (DTMF) is an international signaling standard for telephone digits. These signals are used in touch-tone telephone call signaling as well as many other areas such as interactive control applications, telephone banking, and pager systems. A DTMF signal consists of two superimposed sinusoidal waveforms whose frequencies are chosen from a set of eight standardized frequencies. These frequencies were chosen in Bell Laboratories, where DTMF signaling system were originally proposed as an alternative to pulse dialing system in telephony. The detector part of early DTMF systems consisted of analog implemented bandpass filter-banks, which were tuned to the eight standard frequencies. As analog lines as well as many other analog systems were converted to digital, researchers became interested in digital DTMF detectors. Digital implementation has many advantages over analog implementation such as accuracy, stability, re-programmability, and chip count; that is, instead of using several analog chips for detecting multi-channel DTMF tones, only a digital signal processor (DSP) chip is used for all channels. Many digital DTMF detecting algorithms have been proposed [1], [2], [3], [4] but they have several drawbacks as follows:

1. Most of them do not comply with the related International Telecommunications Union (ITU) and Bellcore recommendations.

2. Some of them have too heavy computational load.

3. Some of them need too much memory to implement on a low cost DSP.

The algorithm proposed by M. D. Felder, J. M. Mason, and B. L. Evans [5],[6] is an efficient DTMF detection algorithm which complies with all ITU and Bellcore speciation’s and does not need any buffering. The inventors, simulated their algorithm on Ptolemy's synchronous data ow (SDF) domain and concluded that this algorithm could be implemented for 24 channels, on a low cost xed point DSP such as the TMS320C50. In this pro ject, my aim was to implement the mentioned algorithm on a TMS320C50 for 24 channels.

# **Background**

A DTMF signal consists of two superimposed sinusoidal waveforms whose frequencies are chosen from a set of eight standardized frequencies. For example, by pressing the \1" button on the touch-tone telephone key pad in Figure 1, a signal consisting of a 697 Hz sinusoid and a 1209 Hz sinusoid is generated. A DTMF detector attempts to detect these frequencies in the presence of noise, and determines which button is pressed.

# B D 123A 7 8 9 C 0 4 6 5 941 770 852 697 Column frequencies (Hz) Row frequencies (Hz) 1209 1336 1477 1633 \* Figure 1: Touch pad in DMTF systems

Detection of frequencies in noisy environment is a well studied area in digital signal processing. The difficulty of DTMF tone detection is due to the standards which must be satisfied when these signals are detected. A summary of ITU and Bellcore's DTMF standards and recommendations are given below:

1) Signal frequencies: Low group (Hz): 697, 770, 852, 941 High group (Hz): 1209, 1336, 1477, 1633

2) Frequency tolerances: a. Frequencies with an o  
set less than 1.5% must be accepted. b. Frequencies with an o  
set more than 3.5% must be rejected.

3) Signal Reception Timing: a. Tones with a duration less than 23 ms must be rejected. b. Tones with a duration more than 40 ms must be accepted. c. An interruption of more than 40 ms must be accepted as a pause (One tone has finished, a new one has started). d. An interruption of less than 10 ms must be tolerated (The tone continuous).

4) Twist (power difference between frequencies):

a. The low frequency may have 8 dB higher power

b. The high frequency may have 4 dB higher power

Bellcore has some recommendations which are in fact a subset of ITU specifications. However, Bellcore does not only give some standards, but also some standardized performance tests as well. Some Bellcore tests and recommendations which are different from ITU specifications are as follows:

1) Bellcore guard time test: Guard time is the minimal length of a tone that can be reliably detected. The guard time is determined by decreasing tone lengths at the input of the detector and counting the number of detects. The receiver guard time is calculated in ms as (500- total detects)/10 and must be under 40 ms.

2) Bellcore power level test: A minimum detection of 25 out of 35 at a tone power of -25 dBm is required. 3) Bellcore talk-o  
 Tests: The most important test might be the talk-o  
 test which determines how often a detector detects a speech as a valid tone. Bellcore provides three one-hour audio tapes which include over 50,000 speech samples, to test a detector. Testing a DTMF detector with all these speech samples is equivalent to testing the detector on one million calls if it was be used in a local central office. Bellcore specified the following allowed false detection numbers: For digits 0-9; 333 for digits 0-9,\*,#; 500 and for digits 0-9,\*,#,A-D; 600. Since these standards were determined when DTMF detectors were analog their aim was to specify optimum analog detectors. For example, the standard frequencies are determined so that they have no common multipliers. This guarantees that none of the frequencies have common harmonics and thereby improves the performance of analog detectors. However, the most commonly used digital frequency analysis technique, the Discrete Fourier Transform (DFT), samples the frequency domain with equally spaced samples, and therefore, it is not possible to have a sample exactly at each standard frequency. This fact guided researchers to use a Non-uniform Discrete Fourier Transform (NDFT) in 5 DTMF detection algorithms. Although it was possible to have arbitrary located samples in frequency domain, more computation was required when using the NDFT. The tradeoff between high frequency resolution and less computational load is the main problem in designing DTMF detectors. The new algorithm [5],[6] complies with all frequency specification of ITU, pasts all Bellcore test, and its computationally efficiency is such that it can be implemented on a DSP for 24 channels. The algorithm is based on NDFT but uses about 30 different modifications. These modifications result in an algorithm which requires no buffering and according to the inventors simulations, requires approximately 1000 words of data memory, 2000 words of program memory and 24 million instructions per second (MIPS) when implementing on a digital signal processor for 24 channels.