PIANO KEY IDENTIFICATION

SUBMITTED IN PARTIAL FULFILLMENT OF THE COURSE

EEE F434 - DIGITAL SIGNAL PROCESSING

Submitted to:

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Above all, we thank each and every one of those who have been instrumental in the successful compilation and presentation of this report.

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Introduction

The **piano** is an acoustic, stringed musical instrument. It is played using a keyboard, which is a row of keys (small levers) that the performer presses down or strikes with the fingers and thumbs of both hands to cause the hammers to strike the strings. Most modern pianos have a row of 88 black and white keys, 52 white keys for the notes of the C major scale (C, D, E, F, G, A and B) and 36 shorter black keys, which are raised above the white keys, and set further back on the keyboard. This means that the piano can play 88 different pitches (or "notes"), going from the deepest bass range to the highest treble. Although the piano is very heavy and thus not portable and is expensive (in comparison with other widely used accompaniment instruments, such as the acoustic guitar), its musical versatility (i.e., its wide pitch range, ability to play chords with up to 10 notes, louder or softer notes and two or more independent musical lines at the same time), the large number of musicians and amateurs trained in playing it, and its wide availability in performance venues, schools and rehearsal spaces have made it one of the Western world's most familiar musical instruments.

In this project, a MATLAB script and a CCS code has been written to distinguish between tones of different frequencies produced by a piano, thus identifying the key which generated the tone.

Assumptions

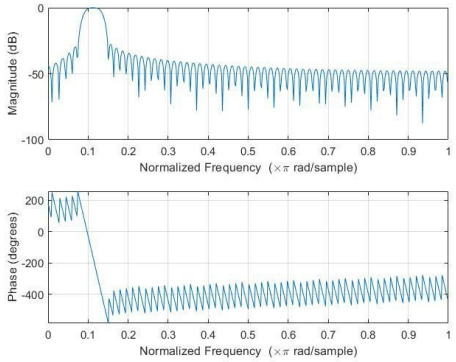
1. *The fundamental frequencies of the tones are not too close to one another*: Since the fundamental frequencies of neighboring keys are very close to each other, it would require a band pass filter with very high quality factor to isolate adjoining keys. Hence, a distinction was established only between keys with frequencies that were sufficiently far part.
2. *Identification of four tones will be performed:* Since a piano has a plethora of frequencies to pick from and it would not be feasible to design so many filters, only four keys were identified.
3. *Surroundings have minimal noise:* For the CCS implementation of the system on a DSK6713 board, the signal input was taken from a function generator, hence minimizing the effect of external noise on the signal being processed.

Considering the above assumptions, the keys 49 (440 Hz), 61 (880 Hz), 73 (1760 Hz) and 85 (3520 Hz) were chosen. They are all harmonics of the A0 tone. Henceforth, these keys will be referred to as A4, A5, A6 and A7 in this report.

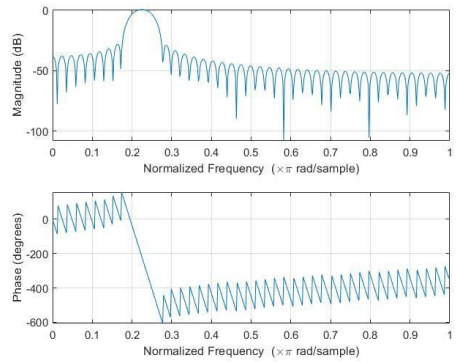
Methodology

The identification of keys was done by passing the tone produced through bandpass filters centered around their fundamental frequency. FIR Kaiser window filters and IIR Chebyshev type - I filters were used, and their coefficients were obtained using the MATLAB Filter Designer tool. The signal is convolved with the transfer function of each filter, and the FFT of the obtained signals is taken. The tone is identified by finding the highest value in each array, and comparing the four highest values to determine the maxima among those. The frequency corresponding to the maxima is the frequency of the key to be identified. The filters were designed using nominal specifications due to the aforementioned assumptions. The sampling frequency is 8000 Hz. Passband attenuation of up to 1 dB is permitted, while the minimum stopband attenuation is 30 dB.

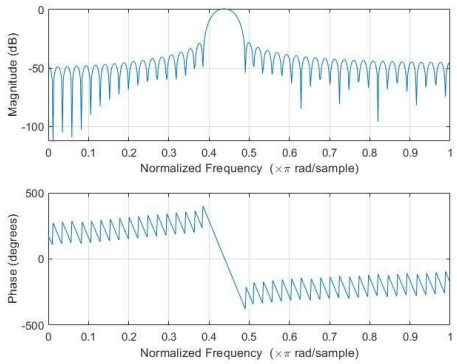
- The frequency response of each FIR filter is displayed in the figures below.



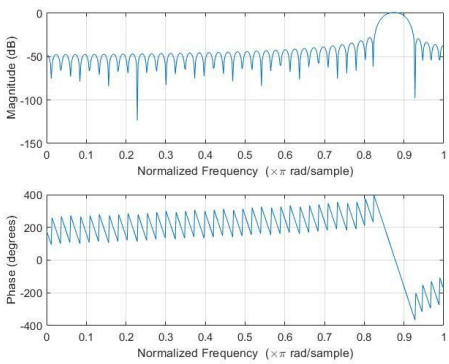
440Hz



880 Hz



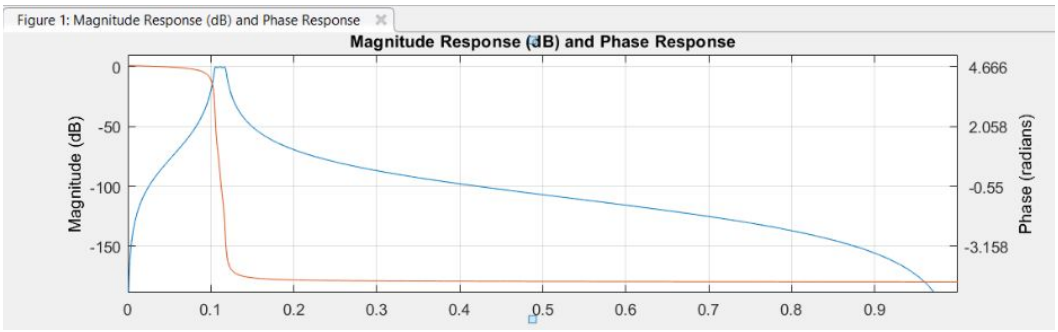
1760 Hz



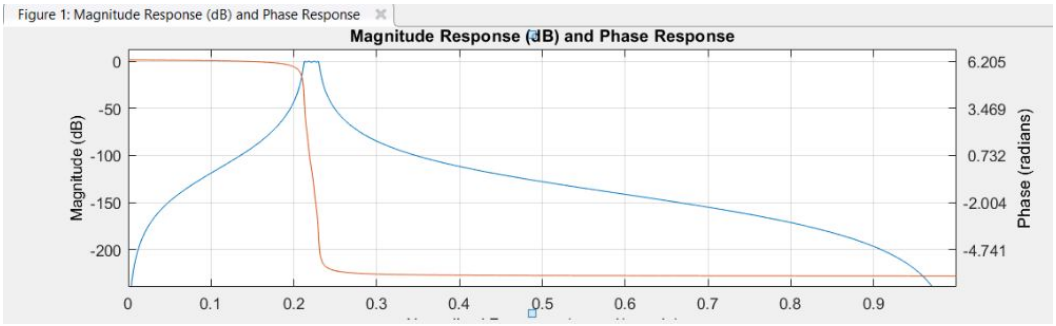
3520 Hz

- The frequency response of the IIR filters is as seen below

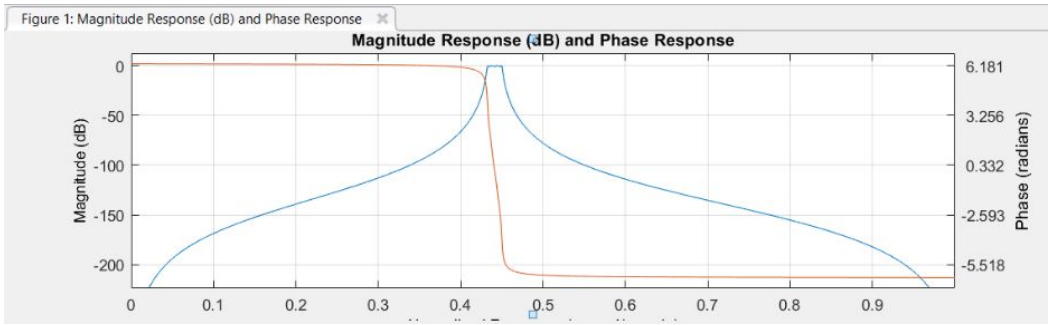
440Hz



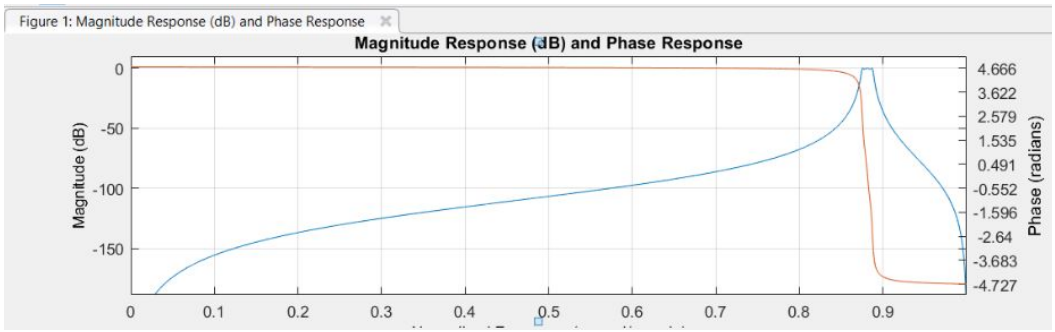
880 Hz



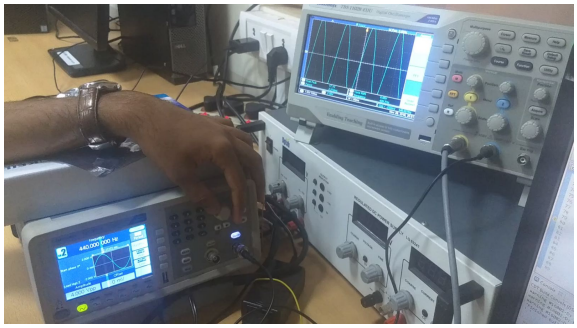
1760 Hz



3520 Hz



For the implementation of the project on Texas Instruments DSK6713 board, the coefficients of the FIR filters created on MATLAB were obtained, and they were fed to a filtering function which performs a convolution operation on the received signal. The aim was to do this for all four filters and compare outputs with one another. But, due to logistical issues, we were able to perform this task for only two filters at a time. The desired output waveform was displayed on a Digital Storage Oscilloscope and the corresponding LED was made dim on the DSK6713 board. The waveform and the LED output for 440 Hz tone were as follows.



An attempt was made to implement the project on the DSK6748 board using IIR filters, but this could not be accomplished within the given timeframe.

Conclusions

The MATLAB implementation for distinguishing between four piano keys yielded successful results using both FIR Kaiser Window filters as well as IIR Chebyshev filters.

The system was also implemented on the DSK6713 signal processing board to distinguish between two tones.

References

1. https://www.mathworks.com/matlabcentral/fileexchange/3785-dtmf-decoder
2. MATLAB help documentation
3. Mitra, Sanjit 2013 "Digital Signal Processing: A Computer-Based Approach 4th Edition"