ECE260 Spring 2019 Project Report 04/26/2019

15-Band LED Audio Frequency Analyzer

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1. Introduction

'15-Band LED Audio Frequency' is a device that records sound from the outside and performs the Fourier Transform to get the amplitude of each frequency component.

2. Developed Solution

- Input: Built-in Omnidirectional MEMS Microphone

  The device is using built-in microphone in the board. It records the sound from the outside and returns the data as PDM format. It is using 3.125MHz clock, and able to represent 15KHz maximum.

- Data Storage: Custom RAM Module

  The device stores PDM data to a custom RAM module. Because of the limited amount of resources of the board. The device is designed to store the audio data for approximately 0.1 seconds.

- Data Processing: 8-bit Sampler & 8-bit Sinewave Look-Up-Table

  The device is handling input audio data as 8-bit unsigned: [0,255], so it is sampling the sequence of 1-bit PDM data to 8-bit sample chunk to process the Fourier Transform.

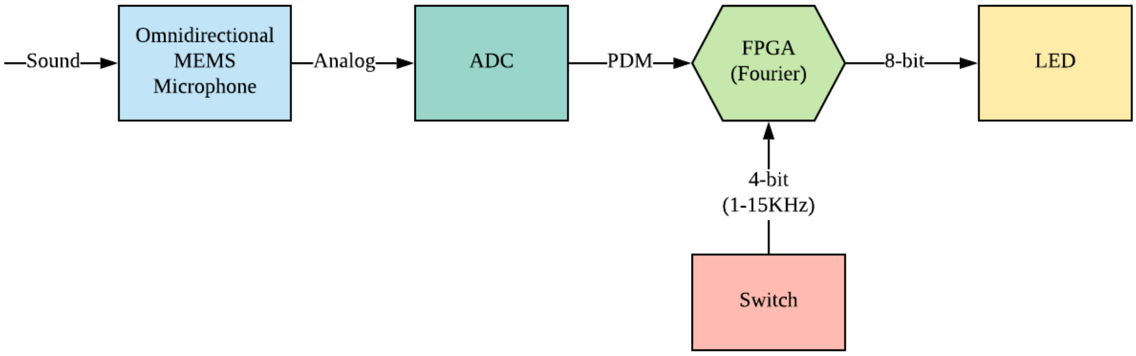
  Also, the device has 8-bit sinewave look-up-table that has one period with 32 phase. The device increments the phase by value from 1(for 1KHz sinewave) to 15(for 15Khz sinewave) based on the input frequency needed to be used in the Fourier Transform.

- Fourier Transform

$$A_f \approx \frac{2}{N}\sum_{n=0}^{N-1} y[n] * s_f[n]$$
$f: frequency(Hz)$
$A_f: Amplitude\ of\ frequency\ component\ f$
$y[n]: 8\ bit\ unsigned\ audio\ data,$
$s_f[n]: 8\ bit\ unsigned\ sinwave\ data\ of\ frequency\ f$
$N: The\ total\ number\ of\ data = 4096$

Since every data is stored in 8-bit unsigned([0,255]), there should be some offset due to the multiplication of each pair of data and the summation. The formula is assuming all data are in floating numbers in the range of [-1,1]. The result above approximately will be $A_f = 16128a_f + 32768$, where a_f is from $a_f(\sin 2\pi * f * t)$ and relatively very small. Therefore, to get meaningful value of amplitude, the device subtracts the offset (32768) and choose 8 LSBs of the result.

3. Block Diagram



4. Schematic

A schematic is included in the project folder as both .sch and .pdf named as following:

ECE260_Project_Schematic_JunsungAhn_04262019.sch

ECE260_Project_Schematic_JunsungAhn_04262019.pdf

5. Bill of Material

No additional devices are used.

6. Results & Discussion

The result is being explained in the video names as following:

ECE260_Project_Video_JunsungAhn_04262019.mov

7. Conclusion

During this project, I realized the big difference between a theoretical approach and a practical implementation. For example, the range of the values of the Fourier transform and the range of values that FPGA can handle are very different, so I needed to find a way to 'map' one range to another range. This mapping led to other problems that needed to be considered, such as some unnecessary offsets. For future implementation, I should find correct way to handle those.