Real-Time Filters

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Real-Time Fourier Transform

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Abstract

This project's goal is to create a visual representation of digital signal processing using a Raspberry Pi Pico board. External components will interface with the Pico to supply digital signals and display the results after processing the signal. A microphone will supply the signal to the Pico which will perform a Fourier Transform on the data and output a spectrogram to a display.

Introduction

The Fourier Transform is a method to convert a function in the time domain into a function in the frequency domain. The function is transformed so each frequency corresponds to its magnitude. Digital signals use a version called the Discrete-Time Fourier Transform (DTFT) that is a form of Fourier analysis on a sequence of values. It uses a discrete sequence in the time domain and produces a periodic function in the frequency domain. The DTFT is defined as the following: $C[k] = \sum_{n=0}^{N} x[n]e^{-2\pi jkn}$ where x[n] is a discrete sequence of real or complex values for all values n.

Objective

Use Raspberry Pi Pico to perform Fourier Transform on audio signals and display its magnitudes at each frequency

Methods

- Signals and code memory within 2MB limit
- Signals must be 3.3V or less
- Signals bust be sampled at a frequency double the signals frequency
- Spectrogram is updated as the input signal changes in time

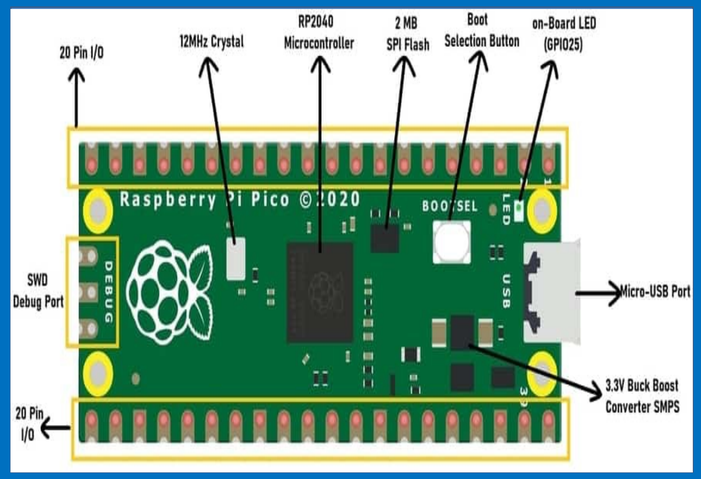

Figure 1. Raspberry Pi Pico board showing the pins, components, and features

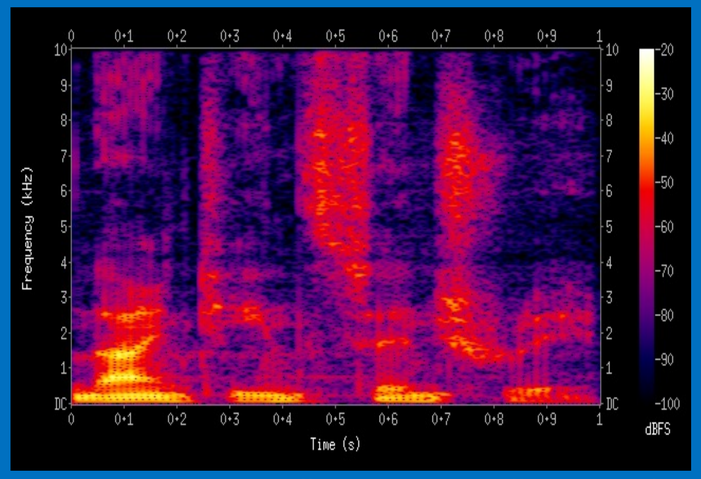

Figure 2. Spectrogram illustrating a signal's magnitude in decibels at each frequency and time.

Figure 3. ILI9341 2.2" LCD screen with SD card

Results

The microprocessor board used (figure 1) includes an analog to digital convertor (ADC) with 10 bits resolution to convert audio signals from a microphone into digital signals. The board also includes a 12MHz clock, 2MB of RAM, and SPI support to communicate with an LCD screen. The resulting spectrogram after using a Fourier Transform of an audio signal shows magnitudes of the signal at each frequency and time (figure 2). Each color on the spectrogram indicates the magnitude strength in decibels (dB). The LCD screen named ILI9341 features a 2.2 inch screen, SPI interface, and an SD card slot for storage.

Discussion/Conclusions/Next Steps

- A similar project samples 64 data points at a time, samples at 16kHz, and only displays 3 colors for magnitudes. My project samples audio at 40kHz (double maximum audio frequency), takes 256 data points at a time, and displays 12 different colors with 32 shades of each color.
- The project visually represents audio signals by using Fourier Transforms to illustrate the magnitudes of different signals at each frequency and point in time.

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