MCEN - 3047

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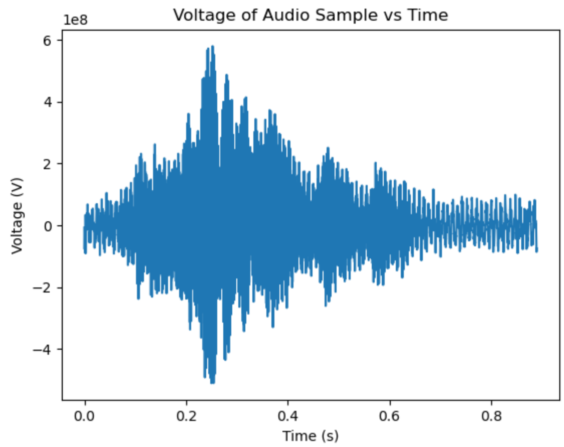
0.1 Problem 1

0.1.1 Part A



0.1.2 Part B

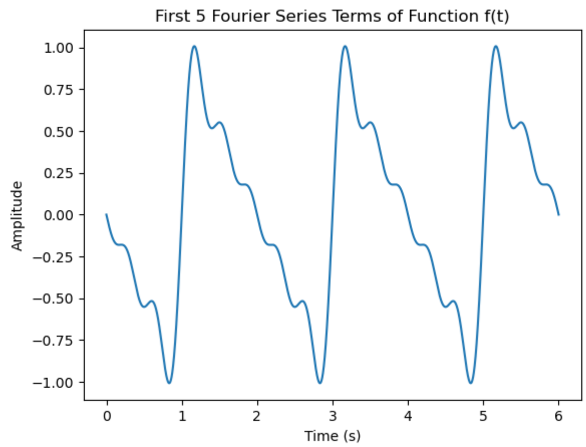
$$\text{LSB} = \text{8-Bit}$$

0.1.3 Part C

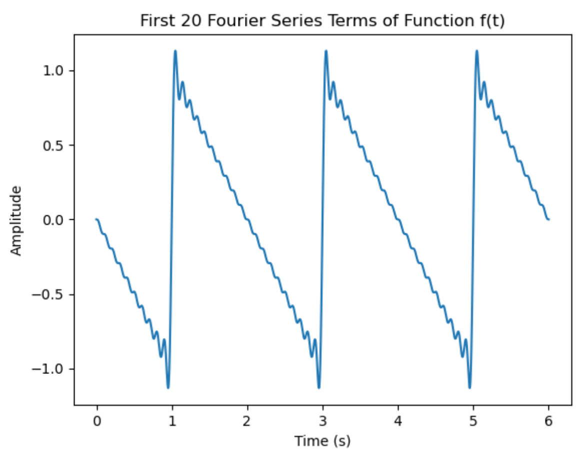
$$V_f s = 709859328.0$$

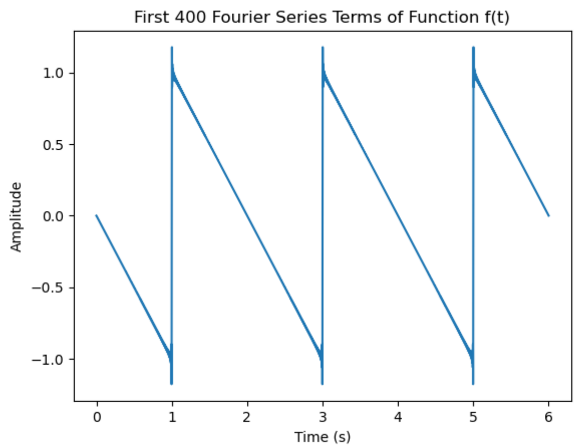
0.2 Problem 2

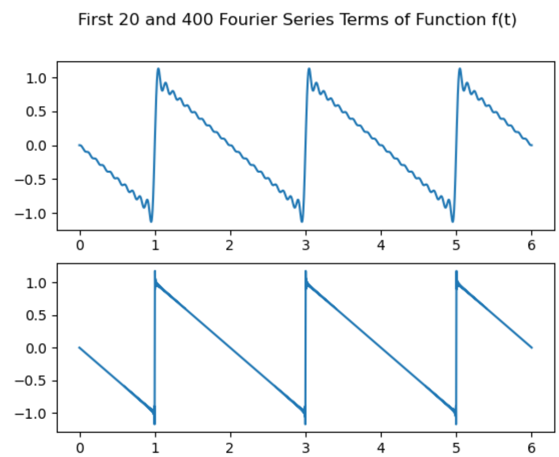
0.2.1 Part A



0.2.2 Part B





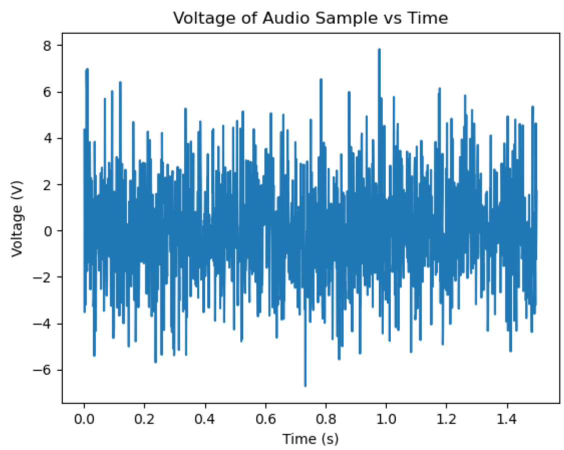


0.2.3 Part C

- The function becomes a better approximation of the cyclical ramp function as n increases, The function appears to become more jagged as n increases as well, better approximating digital signals, if it were one.

0.3 Problem 3

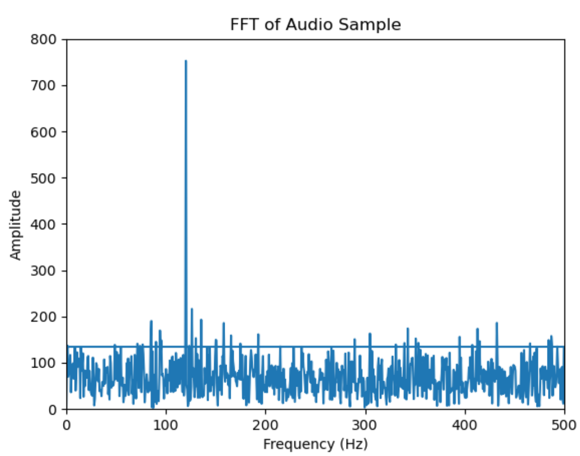
0.3.1 Part A



0.3.2 Part B

It may be possible to get an approximation from this time-series data, however the number may be far from accurate. Thus, one cannot decipher frequency information.

0.3.3 Part C



0.3.4 Part D

Frequency: 120.0800533689126

0.4 CODE

```
import sounddevice as sd
import scipy.io.wavfile as wav
import numpy as np
import matplotlib.pyplot as plt
import torch as tc
import pandas as pd
import os


# I Like Classes
class Set1:
    class Problem1:
        # Calculates the Voltage Range of the DAQ and the
            ↪ Least Significant Bit
        def get_range(self, recording):
            return self.get_step(recording) * (2 ** np.
                ↪ ceil(self.get_nlsb(recording)))

        # finds the smalles difference between two samples
        @staticmethod
        def get_step(recording):
            for i in range(recording.shape[0] - 1):
                diff = np.abs(recording[i] -
                    ↪ recording[i+1])

            return np.min(diff)

        # Calculates the bit number of least significant
            ↪ bit
        def get_nlsb(self, recording):
            v_max = np.max(recording)
            # print(v_max)
            return np.log2(v_max / self.get_step(
                ↪ recording))

        def record_audio(duration=7, fs=44100):
            recording = sd.rec(int(duration * fs),
                ↪ samplerate=fs, channels=2)
            sd.wait()
            return recording
```

```
@staticmethod
def get_num_samples( fs=44100, duration=7):
        return int(fs * duration)

def get_time_vector(self, fs=44100, duration=7):
        num_samples = self.get_num_samples(fs=fs,
            ↪ duration=duration)
        # print(num_samples)
        # print("test")
        return np.linspace(start=0, stop=duration,
            ↪ num=num_samples)


def plot_audio_voltage(self, recording, fs=44100):
        time = self.get_time_vector(fs=fs, duration=
            ↪ len(recording)/fs)
        fig = plt.figure()
        plt.title('Voltage␣of␣Audio␣Sample␣vs␣Time')
        plt.xlabel('Time␣(s)')
        plt.ylabel('Voltage␣(V)')
        plt.plot(time, recording)
        plt.show()

@staticmethod
def plot_audio_fft(recording, fs=44100):

        # recording = recording / np.max(np.abs(
            ↪ recording)) # Normalize amplitude
        # db_data = 20 * np.log10(np.abs(recording)
            ↪ + 1e-10)

        fig = plt.figure()
        plt.title('FFT␣of␣Audio␣Sample')
        plt.xlim(0, 7000)
        plt.ylim(0, 10e11)
        plt.xlabel('Frequency␣(Hz)')
        plt.ylabel('Amplitude')
        plt.plot(np.fft.fftfreq(len(recording), 1/fs
            ↪ ), np.abs(np.fft.fft(recording)))
        plt.show()

def run(self, cat=False):

        if cat:
                sample_rate, recording = wav.read('
                    ↪ ../../data/freyja.wav', 'rb')
```

```
                        self.plot_audio_voltage(recording=
                            ↪ recording, fs=sample_rate)
                        self.plot_audio_fft(recording, fs=
                            ↪ sample_rate)
                else:
                        recording = self.record_audio()
                        self.plot_audio_voltage(recording)
                        self.plot_audio_fft(recording)

                lsb = self.get_nlsb(recording)
                print(f"LSB:␣{np.ceil(lsb)}")
                V_fs = self.get_range(recording)
                print(f"V_fs:␣{V_fs}")

class Problem2:
        @staticmethod
        def compute_function(n=5,duration=6, fs=44100):
                t = np.linspace(start=0, stop=duration, num=
                    ↪ int(fs*duration))
                ten = [(2 * np.cos(np.pi * (i+1)) * np.sin(
                    ↪ np.pi * (i+1) * t )) / (np.pi * (i+1)
                    ↪ ) for i in range(n)]
                ten = tc.tensor(np.array(ten))
                return ten.sum(dim=0), t



        def plot_n_fourier_terms(self, nt=5, duration=6, fs
            ↪ =44100):
                ft, t = self.compute_function(n=nt, duration
                    ↪ =duration, fs=fs)
                fig = plt.figure()
                plt.title(f'First␣{nt}␣Fourier␣Series␣Terms␣
                    ↪ of␣Function␣f(t)')
                plt.xlabel('Time␣(s)')
                plt.ylabel('Amplitude')
                plt.plot(t,ft)
                plt.show()


        def double_plot_n_fourier_terms(self, n1=20, n2
            ↪ =400, duration=6, fs=44100):
                f1, t = self.compute_function(n=n1, duration
                    ↪ =duration, fs=fs)
                f2, t = self.compute_function(n=n2, duration
                    ↪ =duration, fs=fs)
```

```
        fig, axs = plt.subplots(2)
        fig.suptitle('First␣20␣and␣400␣Fourier␣
            ↪ Series␣Terms␣of␣Function␣f(t)')
        axs[0].plot(t, f1)
        axs[1].plot(t, f2)
        plt.show()

    def run(self):
        self.plot_n_fourier_terms(nt=5)
        self.plot_n_fourier_terms(nt=20)
        self.plot_n_fourier_terms(nt=400)
        self.double_plot_n_fourier_terms()



class Problem3:
    """ 1. Takes a csv file, tone, that contains audio
        ↪ data.
    i. The first column is the time vector
    ii. The second column is the audio data
    2. Executes a FFT on the audio
    3. plots the timeseries data
    4. plots the FFT data
    5. Saves the plots as images
    6. calculates the frequency of the tone from the
        ↪ least significant bit of the DAQ
    and voltage scale"""
    def run(self):
        df = self.read_csv()
        self.plot_audio(df)
        self.plot_audio_fft(df)
        self.calculate_peak_frequency(df)
        # self.save_plots(df)

    def read_csv(self, file_path='tone.csv', home=True)
        ↪ :
        if home:
            file_path = os.path.join('../../data
                ↪ /', file_path)


            df = pd.read_csv(file_path)

            df.columns = ['time', 'audio']
        return df
```

```
        def plot_audio(self, df):
                fig = plt.figure()
                plt.title('Voltage of Audio Sample vs Time')
                plt.xlabel('Time (s)')
                plt.ylabel('Voltage (V)')
                plt.plot(df['time'], df['audio'])
                plt.show()

        def plot_audio_fft(self, df):

                sample_rate = (df['time'][1] - df['time'
                    ↪ ][0]) ** -1
                fig = plt.figure()
                plt.title('FFT of Audio Sample')
                plt.xlim(0, 500)
                plt.ylim(0, 800)
                plt.xlabel('Frequency (Hz)')
                plt.ylabel('Amplitude')
                plt.plot(np.fft.fftfreq(len(df['audio']), 1/
                    ↪ sample_rate), np.abs(np.fft.fft(df['
                    ↪ audio'])))
                plt.show()
                def save_plots(self, df, file_path='results'
                    ↪ , home=True):
                if home:
                file_path = os.path.join('../../', file_path
                    ↪ )

                self.plot_audio(df)
                self.plot_audio_fft(df)
                print("Saving plots...")
                plt.savefig(file_path + '/problem3.png')

        def calculate_peak_frequency(self, df):
                sample_rate = (df['time'][1] - df['time'
                    ↪ ][0]) ** -1
                freq_bins = np.fft.fftfreq(len(df['audio']),
                    ↪  1/sample_rate)
                freq_amps = np.abs(np.fft.fft(df['audio']))

                loc, val = np.argmax(freq_amps), np.max(
                    ↪ freq_amps)
                print(f"Peak Frequency: {freq_bins[loc]}")


def run(self):
```

```
        """ Runs the Entire problem set """

                print("Running␣Problem␣1")
                p1 = self.Problem1()
                p1.run(cat=True)

                print("Running␣Problem␣2")
                p2 = self.Problem2()
                p2.run()

                print("Running␣Problem␣3")
                p3 = self.Problem3()
                p3.run()


# Easy Execution with "python set_1.py"
s1 = Set1()
print("Running␣Set␣1")
s1.run()
```