Week 7: Tremolo/Beats Effects 2

Laboratory 6

Last updated February 25, 2023

00. Content

Mathematics

- Laws of sines/cosines

Programming Skills

- Type here

Embedded Systems

- N/A

0. Required Hardware

- headphones

Write your name and email below:

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1. Building a Voice Recorder

Before we begin, we need to install a library which will help us in manipulating audio with python. We will be using PyAudio for this purpose as it is easy to use and works on a variety of different environments.

Installation instructions for PyAudio can be found from here.

To explore more in detail about PyAudio and its features, you could refer the API docementation for PyAudio

For Recording Audio with Python, we have to do the following:

1. Open a data stream to get audio data frame from microphone
2. Iterate over the stream and append each frame to a list of frames.
3. Stop and close the data stream.
4. Save the data frames as a .wave file.

voice_recorder.py is implemented following the above pseudo code. It records 5s of mono channel audio and saves it as my_recording.wave

Exercise 1

Run voice_recorder.py and report your observations.

The recording process was pretty quick and worked well. The recording seems good enough.

Exercise 2

Modify the voice_recorder.py to record a 10s audio recording of yourself and save it as _voice_clip.wave

In [46]:
```
#!/usr/bin/env python

"""voice_recorder.py: As the name indicates, this code is used to record auc

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import pyaudio
import wave


chunk = 1024
FORMAT = pyaudio.paInt16
CHANNELS = 1
RATE = 44100
RECORD_SECONDS = 10
OUTPUT_FILE_NAME = "aidan_voice_clip.wav"

p = pyaudio.PyAudio()

stream = p.open(format = FORMAT,
                channels = CHANNELS,
                rate = RATE,
                input = True,
                frames_per_buffer = chunk)

frames = list()

print("*************************************")
print("*******   recording started   *******")

for i in range(0, RATE//chunk * RECORD_SECONDS):

    frame = stream.read(chunk, exception_on_overflow = False)
    frames.append(frame)


print("******   recording completed   ******")
print("*************************************")


stream.stop_stream()
stream.close()
p.terminate()

print("----  saving audio as .wav file  ----")
print("*************************************")

file = wave.open(OUTPUT_FILE_NAME, 'wb')
file.setnchannels(CHANNELS)
file.setsampwidth(p.get_sample_size(FORMAT))
file.setframerate(RATE)
file.writeframes(b''.join(frames))
file.close()
```

```
***********************************
*******   recording started   *******
******   recording completed   ******
***********************************
----  saving audio as .wav file  ----
***********************************
```

Exercise 3

Write a Python code to play the recorded audio using PyAudio. Hint: set mode as output while creating the stream object.

In [2]:
```
import pyaudio
import wave


chunk = 1024
FORMAT = pyaudio.paInt16
CHANNELS = 1
RATE = 44100
RECORD_SECONDS = 10
INPUT_FILE_NAME = "./aidan_voice_clip.wav"

p = pyaudio.PyAudio()

stream = p.open(format = FORMAT,
                channels = CHANNELS,
                rate = RATE,
                output = True,
                frames_per_buffer = chunk)

file = wave.open(INPUT_FILE_NAME, 'rb')
output = file.readframes(RATE * RECORD_SECONDS)
# file.setnchannels(CHANNELS)
# file.setsampwidth(p.get_sample_size(FORMAT))
# file.setframerate(RATE)
stream.write(output)
file.close()
```

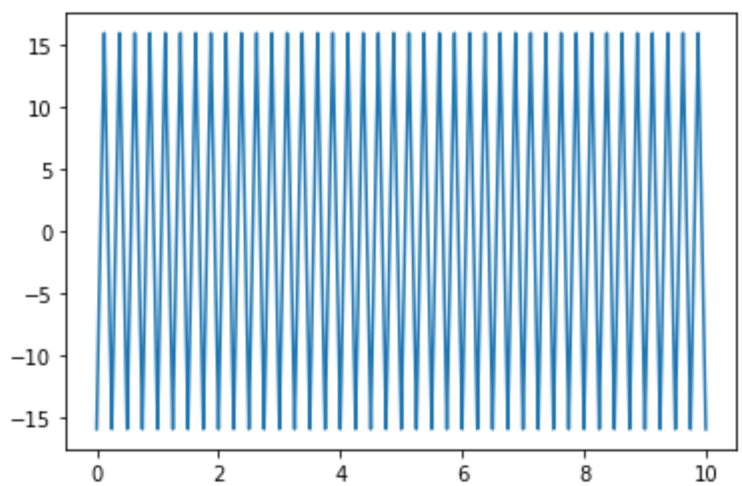
Exercise 4

Modulate the sound of your voise with the triangular wave and play the modulated sound Change the triagular wave frequency and play the resulting modulated sound. Compare what happens when the frequency is very low (<20Hz) and when it is very high (20-20kHZ).

In [15]:
```
import numpy as np
from scipy.io import wavfile
import matplotlib.pyplot as plt
from IPython.display import Audio

def triangle(freq, n):
    """
    freq = frequency of the triangle wave
    n = the length of the wave in seconds
    """
    t = np.linspace(0, n, n * 44100)
    T = 1 / freq
    amplitude = 8 / T
    return amplitude * (2 * np.abs(t / T - np.floor(t / T + 1 / 2)) - 0.5)
```

In [9]:
```
tri = triangle(4, 10)
t = np.linspace(0, 10, 10 * 44100)

plt.plot(t, tri)
```

Out[9]: [<matplotlib.lines.Line2D at 0x7fb86f3088e0>]



In [23]:
```
tri = triangle(4, 10)
tri = np.array(tri, dtype="int16")

(rate, input_array) = wavfile.read('aidan_voice_clip.wav')

Audio(input_array, rate = RATE)
```

Out[23]: 0:00 / 0:10

In [24]:
```
mod_voice = tri * np.append(input_array, [0 for i in range(len(tri) - len(ir

Audio(mod_voice, rate = RATE)
```

Out[24]: 0:00 / 0:10

In [27]:
```
tri = triangle(200, 10)
mod_voice = tri* np.append(input_array, [0 for i in range(len(tri) - len(inp

Audio(mod_voice, rate=RATE)
```

Out[27]:

0:00 / 0:10

In [28]:
```
tri = triangle(2000, 10)
mod_voice = tri* np.append(input_array, [0 for i in range(len(tri) - len(inp

Audio(mod_voice, rate=RATE)
```

Out[28]:

0:00 / 0:10

When the frequency is very low, it almost sounds like the sample is slowed down, and you can very easily follow the ups and downs of the triangle wave. When it is much faster, the recording sounds very digital and scratchy, and if it's too high it is difficult to understand.

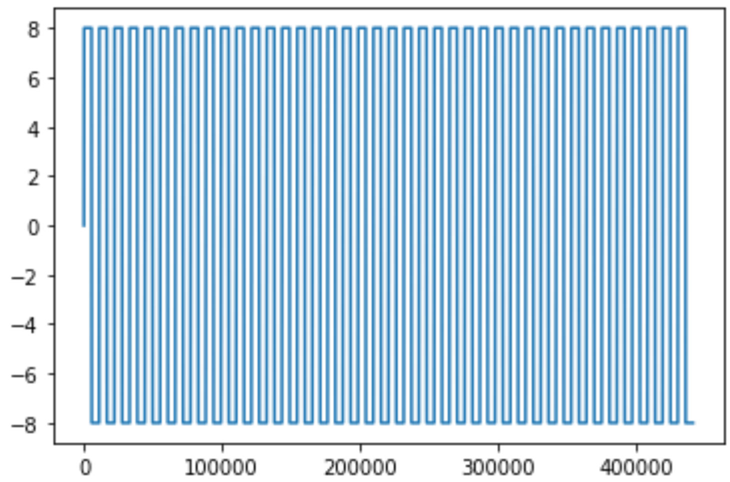
Exercise 5

Modulate the sound of your voise with the square wave and play the modulated sound.

In [36]:
```
def square(freq, n):
    """
    freq = frequency of the triangle wave
    n = the length of the wave in seconds
    """
    t = np.linspace(0, n, n * 44100)
    amplitude = 2 * freq
    x = np.sin(2 * np.pi * freq * t)
    return np.sign(x) * amplitude
```

In [37]:
```
plt.plot(square(4, 10))
```

Out[37]:
```
[<matplotlib.lines.Line2D at 0x7fb855977160>]
```



In [38]:
```
sq = square(4, 10)
mod_voice = sq * np.append(input_array, [0 for i in range(len(tri) - len(inp

Audio(mod_voice, rate=RATE)
```

Out[38]:

0:00 / 0:10

In [42]:
```
sq = square(2000, 10)
mod_voice = sq * np.append(input_array, [0 for i in range(len(tri) - len(inp

Audio(mod_voice, rate=RATE)
```

Out[42]:

0:00 / 0:10

Create your own modulation effect

Exercise 6

Create the signal $x(t)$ a recording of you saying "B'Euler up!".

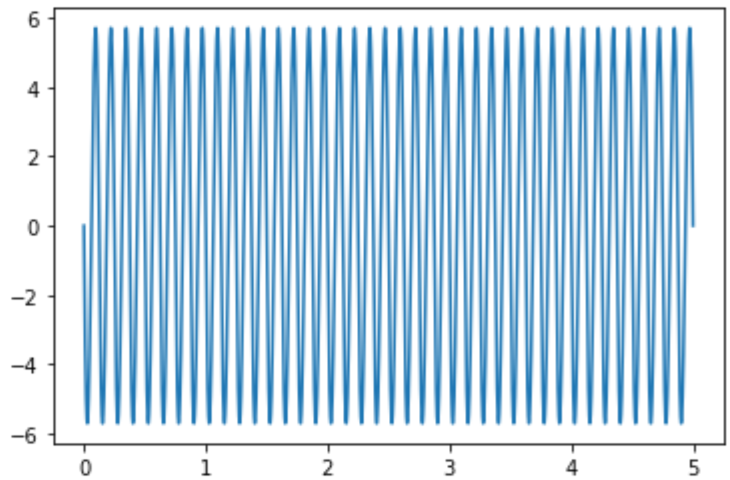
In [47]:
```
x = wavfile.read('boiler_up.wav')[1]
```

Exercise 7

Create an original periodic signal $c_1(t)$. Use it to modulate $x(t)$ and play the resulting modulated signal.

In [76]:
```
t = np.linspace(0, 5, 5 * 44100)

c_1 = np.sin(2 * np.pi * 4 * t) * triangle(4, 5)
plt.plot(t, c_1)
```

Out[76]: [<matplotlib.lines.Line2D at 0x7fb8553e0970>]



In [77]:
```
mod_recording = c_1 * np.append(x, [0 for i in range(len(c_1) - len(x))])
Audio(mod_recording, rate=RATE)
```

Out[77]:

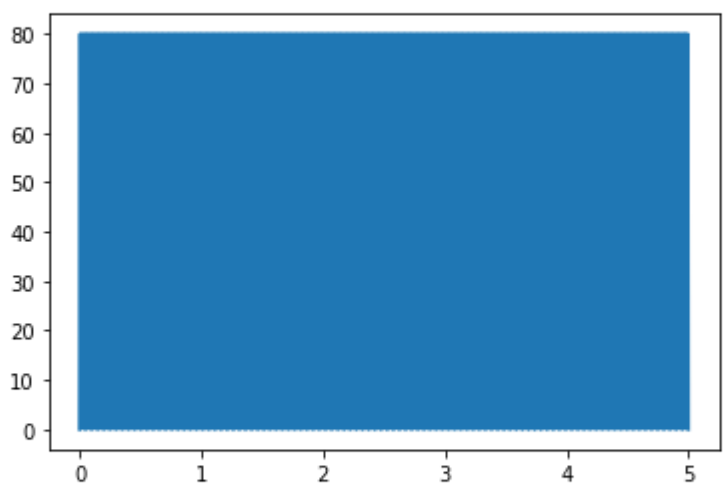
0:00 / 0:05

Exercise 8

Create another original periodic signal $c_2(t)$ with the same frequency as $c_1(t)$. Use it to modulate $x(t)$ and play the resulting modulated signal.

In [78]:
```
c_2 = np.sin(2 * np.pi * 40 * t) * square(40, 5)
plt.plot(t, c_2)
```

Out[78]: [<matplotlib.lines.Line2D at 0x7fb855540490>]



In [79]:
```
mod_recording = c_2 * np.append(x, [0 for i in range(len(c_1) - len(x))])
Audio(mod_recording, rate=RATE)
```

Out[79]:

0:00 / 0:05

Exercise 9

Play the signal $x(t)c_1(t)c_2(t)$. Describe that signal.

In [80]:
```
mod_recording = c_1 * c_2 * np.append(x, [0 for i in range(len(c_1) - len(x)
Audio(mod_recording, rate=RATE)
```

Out[80]:

0:00 / 0:05

This signal is very messy, however much different from the original recording.

Exercise 10

Play the signal $x(t)(c_1(t) + c_2(t))$. Describe that signal.

In [81]:
```
mod_recording = (c_1 + c_2) * np.append(x, [0 for i in range(len(c_1) - len(
Audio(mod_recording, rate=RATE)
```

Out[81]:

0:00 / 0:05

This one kinda just sounds like the first modulation I had in Excerise 7; Very electronic and distorted.

2. Instrument Tuning with "beats"

Orchestra players are well familiar with the tremolo effect, which they call "beats", as they use it to tune their instruments.

The idea is the following: if two instruments play the same note, then the sound produced corresponds to the addition of two periodic signals. For simplicity, let's assume that the first instrument plays a cosine wave at a frequency f_a:

$$x_a(t) = \cos 2\pi f_a t,$$

and let's assume that the second instrument plays another cosine wave at a similar (but not equal) frequency f_b:

$$x_b(t) = \cos 2\pi f_b t.$$

Then the combined sound is

$$x(t) = x_a(t) + x_b(t) = \cos 2\pi f_a t + \cos 2\pi f_b t.$$

Exercise 11

Assume $f_a = 400Hz$ and $f_b = 410Hz$. Write $x(t)$ as a product of two sine waves.

$$x(t) = \frac{1}{2}\cos(2\pi 400t) - \frac{1}{2}\cos(2 * \pi 410t)$$

$$x(t) = \sin\left(2\pi\left(\frac{400+410}{2}\right)t\right)\sin\left(2\pi\left(\frac{410-400}{2}\right)\right)$$

$$x(t) = \sin(2\pi 405t)\sin(2\pi 5)$$

To understand what happens in general, we replace f_1 by $\frac{f_a+f_b}{2}$ and f_2 by $\frac{f_b-f_a}{2}$ in the equation above. This gives us

$$\sin\left(2\pi\left(\frac{f_a+f_b}{2}\right)t\right)\sin\left(2\pi\left(\frac{f_b-f_a}{2}\right)t\right) = \frac{1}{2}\cos(2\pi f_a t) - \frac{1}{2}\cos(2\pi f_b t).$$

In other words, two cosine waves with a similar frequency added together correspond to modulating a sine wave at the average frequency with a (carrier) sine wave at half the frequency difference. If f_1 and f_2 are close frequencies in the audible range, then their difference is small. Therefore, one expects a tremolo effect to occur when the instruments are not in tune.

Exercise 12

Suppose the signals $\sin(2\pi 440t)$ (a middle A) and the signal $\sin(2\pi 442t)$ are added together. What would be the frequency of the carrier (i.e., the beat/tremolo frequency)? Play the added signals: do you hear the beats? Plot the modulated signal: is it the same? Plot a few cycles of each signal (added and modulated) and compare.

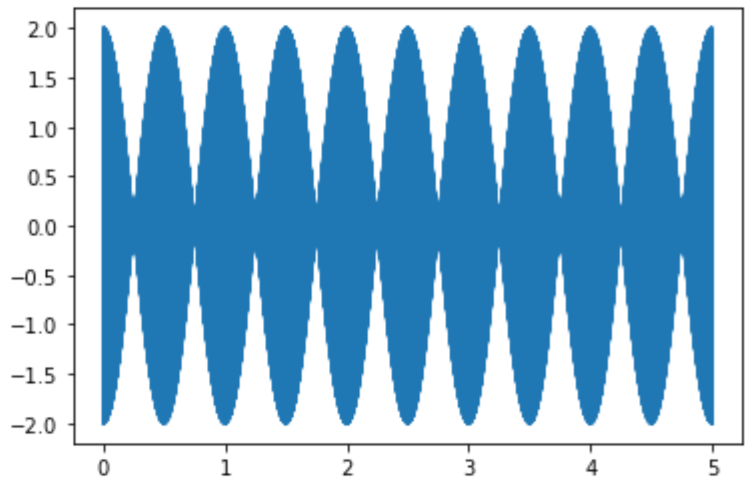
In [93]:
```
f_a = 440
f_b = 442

x = np.sin(2 * np.pi * f_a * t) + np.sin(2 * np.pi * f_b * t)
Audio(x, rate=RATE)
```

Out[93]:

0:00 / 0:05

In [96]:
```
plt.plot(t, x)
```

Out[96]:
```
[<matplotlib.lines.Line2D at 0x7fb853937a90>]
```

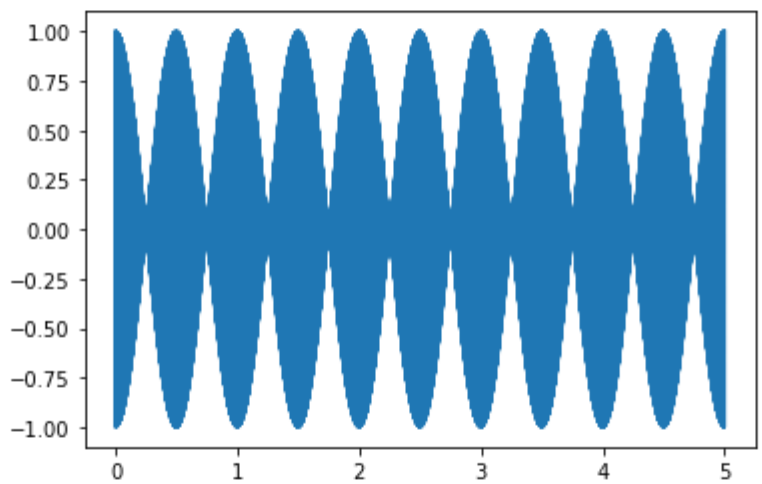


In [94]:
```
modulated = np.cos(2 * np.pi * (f_a + f_b) / 2 * t) * np.cos(2 * np.pi * (f_
Audio(modulated, rate=RATE)
```

Out[94]: 0:00 / 0:05

In [95]:
```
plt.plot(t, modulated)
```

Out[95]: [<matplotlib.lines.Line2D at 0x7fb84c0f1100>]



Exercise 13

Can two musicians listening to the added sounds determine the difference between the frequencies of their instruments? If so, how? If not, why not.

Most musicians can tell the relative difference between their instruments I think, meaning they can move their pitch higher and lower and figure out if the beats get worse or better. From there they can determine which way they need to go to match pitch.

Exercise 14

Can two musicians playing out-of-tune instruments use the beat phenomenon so to tune their instrument in such a way that they play an A at the 440Hz frequency? If so, how? If not, explain why not.

Yes, musicians can use the beat phenomenon to tune their out-of-tune instruments together. They do this my paying attention to the frequency of the beats, the slower the beats are, the closer the musicians are to the same note.

Reflection

Do not skip this section! Lab will be graded only on completion of this section.

__1. What parts of the lab, if any, do you feel you did well?

1. What are some things you learned today?
2. Are there any topics that could use more clarification?
3. Do you have any suggestions on parts of the lab to improve?__

Write Answers for the Reflection Below

1. I think I did part 1 fairly well, thanks to the tip about simplifying the audio output.
2. I learned how you can use different waves to modulate recordings in certain ways.
3. I was a bit confused when performing excersises 11 and 12, mainly because I wasn't sure what they were asking for. Can you model the addition of sine waves the same way we did cosines in the example?
4. If you could explain the process of modeling the addition of two waves better from exercise 11, I think that would help a lot.