analogue_filters

October 31, 2023

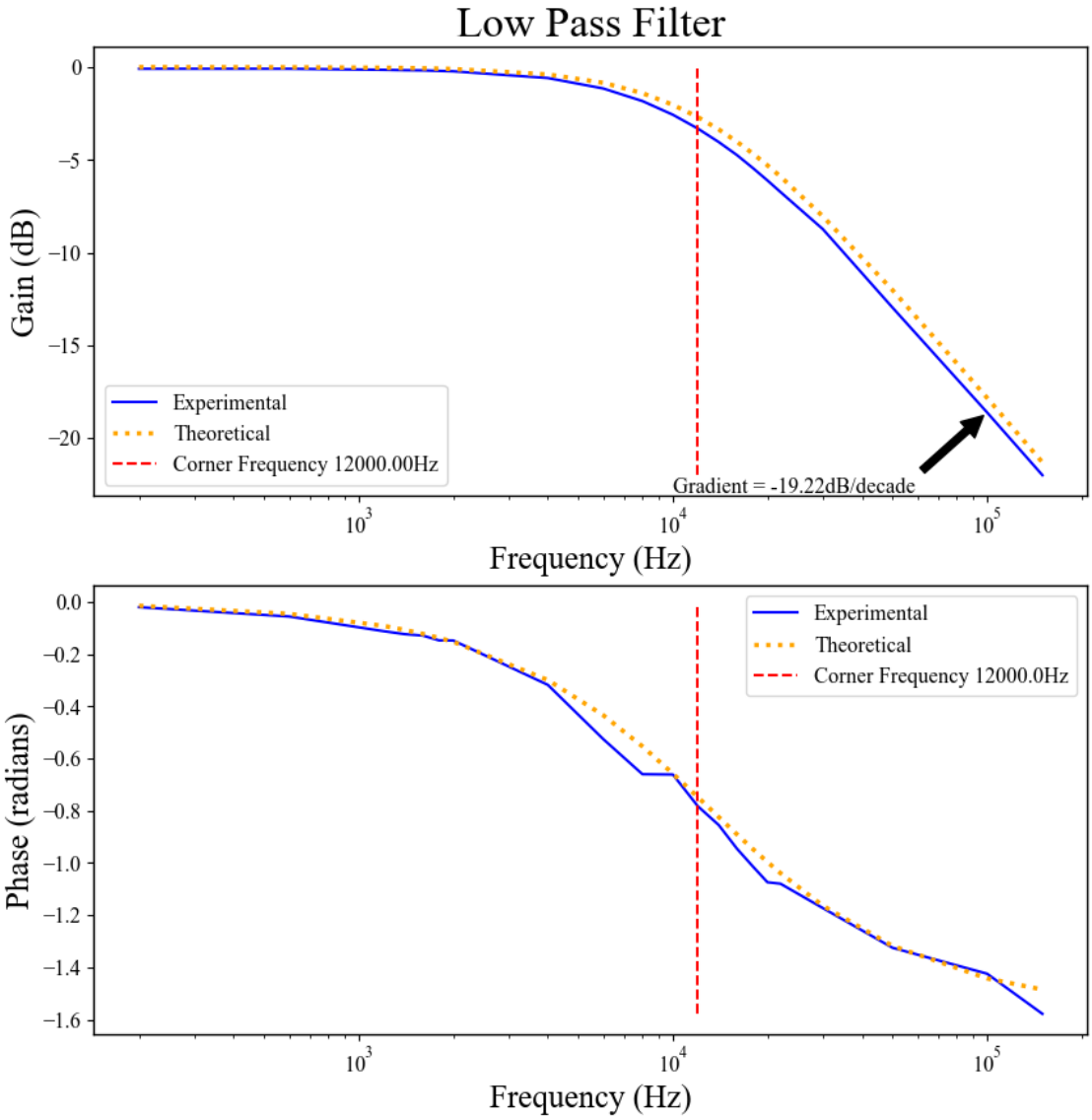
[ ]:
```
import numpy as np
import matplotlib.pyplot as plt
import scipy as sp
from scipy.optimize import curve_fit
from scipy import interpolate
import os
import pandas as pd
plt.style.use('../report.mplstyle')
import csv
import re
```

[ ]:
```
files = os.listdir('data/')

for file in files:
    if file.endswith('.csv'):
        os.rename('data/'+file, 'data/moku_csv/'+file)

    elif file.endswith('.png'):
        os.rename('data/'+file, 'data/moku_images/'+file)

def float_array_convert(array):
    return np.array([float(i) for i in array])

lp_data = pd.read_csv('data/csv/lp_data.csv',sep = ',')
hp_data = pd.read_csv('data/csv/hp_data.csv',sep = ',')

lp_peak_to_peak, lp_phase, lp_freq = lp_data['peaktopeak'], lp_data['phase'],␣
 ↪lp_data['frequency']
hp_peak_to_peak, hp_phase, hp_freq = hp_data['peaktopeak'], hp_data['phase'],␣
 ↪hp_data['frequency']

lp_peak_to_peak, lp_phase, lp_freq = float_array_convert(lp_peak_to_peak),␣
 ↪float_array_convert(lp_phase), float_array_convert(lp_freq)
hp_peak_to_peak, hp_phase, hp_freq = float_array_convert(hp_peak_to_peak),␣
 ↪(float_array_convert(hp_phase))-np.pi/2, float_array_convert(hp_freq)
```

[ ]:
```
def arctan(x,r,c):
    return -np.arctan(x*r*c)

def corner_freq(x,y):
    return np.full_like(y,x[np.argmin(np.abs(y+3))])

def gradient(x,y):
    return np.gradient(x,y)

lp_resistance = 15000
lp_capacitance = 0.82e-9

log_lp_gain = 20*np.log10(lp_peak_to_peak)
lp_omega = (lp_freq*2*np.pi)
log_lp_omega = np.log10(lp_omega)
log_lp_theo_gain = 20*np.log10(1/np.
 ↪sqrt(1+(lp_omega*lp_resistance*lp_capacitance)**2))
lp_theo_phase = arctan(lp_omega,lp_resistance,lp_capacitance)
lp_corner_freq = corner_freq(lp_freq,log_lp_gain)

print((np.abs(log_lp_gain)))

plt.figure(figsize=(10,10))
plt.subplot(2,1,1)
plt.plot(lp_freq,log_lp_gain, label = 'Experimental', color = 'blue')
plt.plot(lp_freq,log_lp_theo_gain, label = 'Theoretical', color = 'orange',␣
 ↪linestyle = ':', linewidth = 2.5)
plt.plot(lp_corner_freq,log_lp_gain, label = f'Corner Frequency␣
 ↪{lp_corner_freq[0]:.2f}Hz', color = 'red', linestyle = '--', linewidth = 1.5)
plt.annotate(f'Gradient = {gradient(log_lp_gain,log_lp_omega)[-1]:.2f}dB/
 ↪decade', xy = (lp_freq[-2],log_lp_gain[-2]), arrowprops=dict(facecolor =␣
 ↪'black', shrink = 0.05,), xytext = (lp_freq[-2]-90000,log_lp_gain[-2]-4.3))
plt.xlabel(r'Frequency (Hz)')
plt.xscale('log')
plt.ylabel('Gain (dB)')
plt.title('Low Pass Filter')
plt.legend()
plt.subplot(2,1,2)
plt.plot(lp_freq,lp_phase, label = 'Experimental', color = 'blue')
plt.plot(lp_freq,lp_theo_phase, label = 'Theoretical', color = 'orange',␣
 ↪linestyle = ':', linewidth = 2.5)
plt.plot(lp_corner_freq,lp_phase, label = f'Corner Frequency␣
 ↪{lp_corner_freq[0]}Hz', color = 'red', linestyle = '--', linewidth = 1.5)
plt.xlabel(r'Frequency (Hz)')
plt.xscale('log')
plt.ylabel('Phase (radians)')
plt.legend()
```

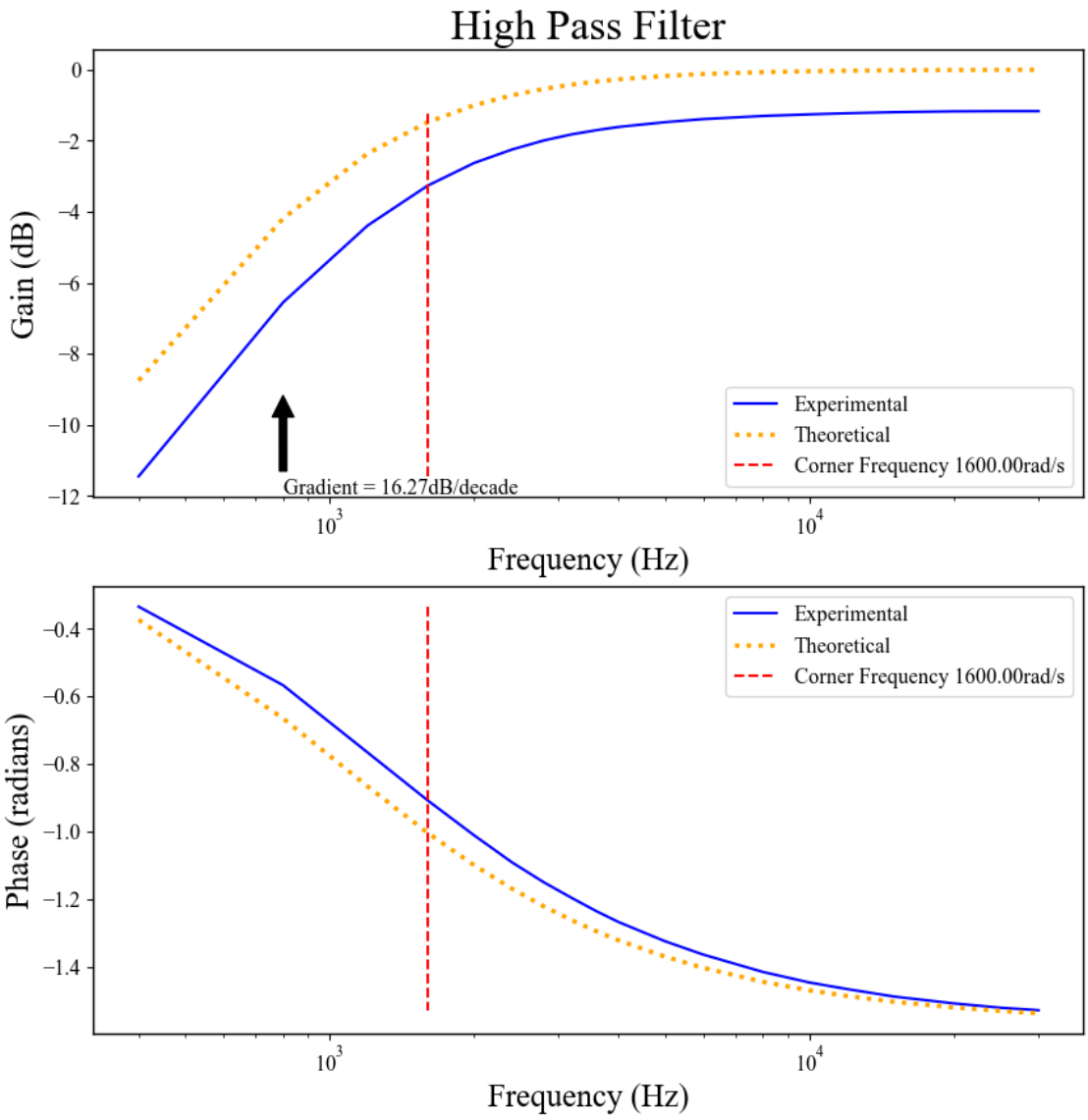
```
plt.show()
```

```
[ 0.09343982  0.09343982  0.14804608  0.16927649  0.17991119  0.20744459
  0.22882086  0.59027302  1.15289301  1.83351721  2.57087652  3.31540194
  4.04495743  4.74792901  5.45405594  6.11491776  6.7372937   8.73512598
 12.96793855 18.62144777 22.00577811]
```



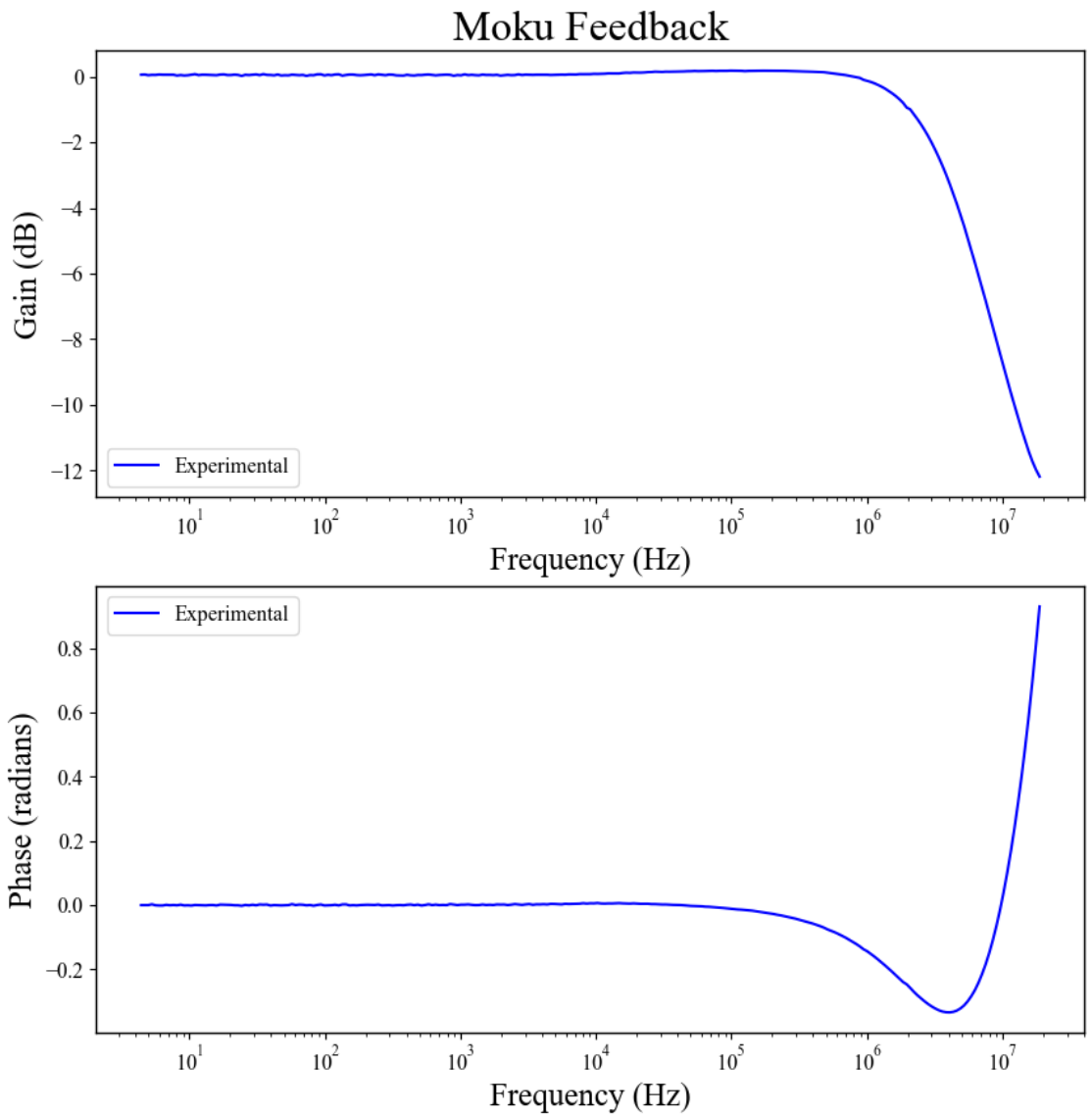
[ ]:
```
hp_resistance = 156000
hp_capacitance = 1e-9

log_hp_gain = 20*np.log10(hp_peak_to_peak)
hp_omega = (hp_freq*2*np.pi)
```

```
log_hp_omega = np.log10(hp_omega)
log_hp_theo_gain = 20*np.log10(hp_omega*hp_resistance*hp_capacitance/(np.
 ↪sqrt(1+(hp_omega*hp_resistance*hp_capacitance)**2)))
hp_theo_phase = arctan(hp_omega,hp_resistance,hp_capacitance)
hp_corner_freq = corner_freq(hp_freq,log_hp_gain)


plt.figure(figsize=(10,10))
plt.subplot(2,1,1)
plt.plot(hp_freq,log_hp_gain, label = 'Experimental', color = 'blue')
plt.plot(hp_freq,log_hp_theo_gain, label = 'Theoretical', color = 'orange',␣
 ↪linestyle = ':', linewidth = 2.5)
plt.plot(hp_corner_freq,log_hp_gain, label = f'Corner Frequency␣
 ↪{hp_corner_freq[0]:.2f}rad/s', color = 'red', linestyle = '--', linewidth =␣
 ↪1.5)
plt.annotate(f'Gradient = {gradient(log_hp_gain,log_hp_omega)[0]:.2f}dB/
 ↪decade', xy = (hp_freq[1]-0.165,log_hp_gain[1]-2.5),␣
 ↪arrowprops=dict(facecolor = 'black', shrink = 0.05,), xytext = (hp_freq[1]+0.
 ↪1,log_hp_gain[1]-5.4))
plt.xlabel('Frequency (Hz)')
plt.xscale('log')
plt.ylabel('Gain (dB)')
plt.title('High Pass Filter')
plt.legend()
plt.subplot(2,1,2)
plt.plot(hp_freq,hp_phase, label = 'Experimental', color = 'blue')
plt.plot(hp_freq,hp_theo_phase, label = 'Theoretical', color = 'orange',␣
 ↪linestyle = ':', linewidth = 2.5)
plt.plot(hp_corner_freq,hp_phase, label = f'Corner Frequency {hp_corner_freq[0]:
 ↪.2f}rad/s', color = 'red', linestyle = '--', linewidth = 1.5)
plt.xlabel('Frequency (Hz)')
plt.xscale('log')
plt.ylabel('Phase (radians)')
plt.legend()
plt.show()
```

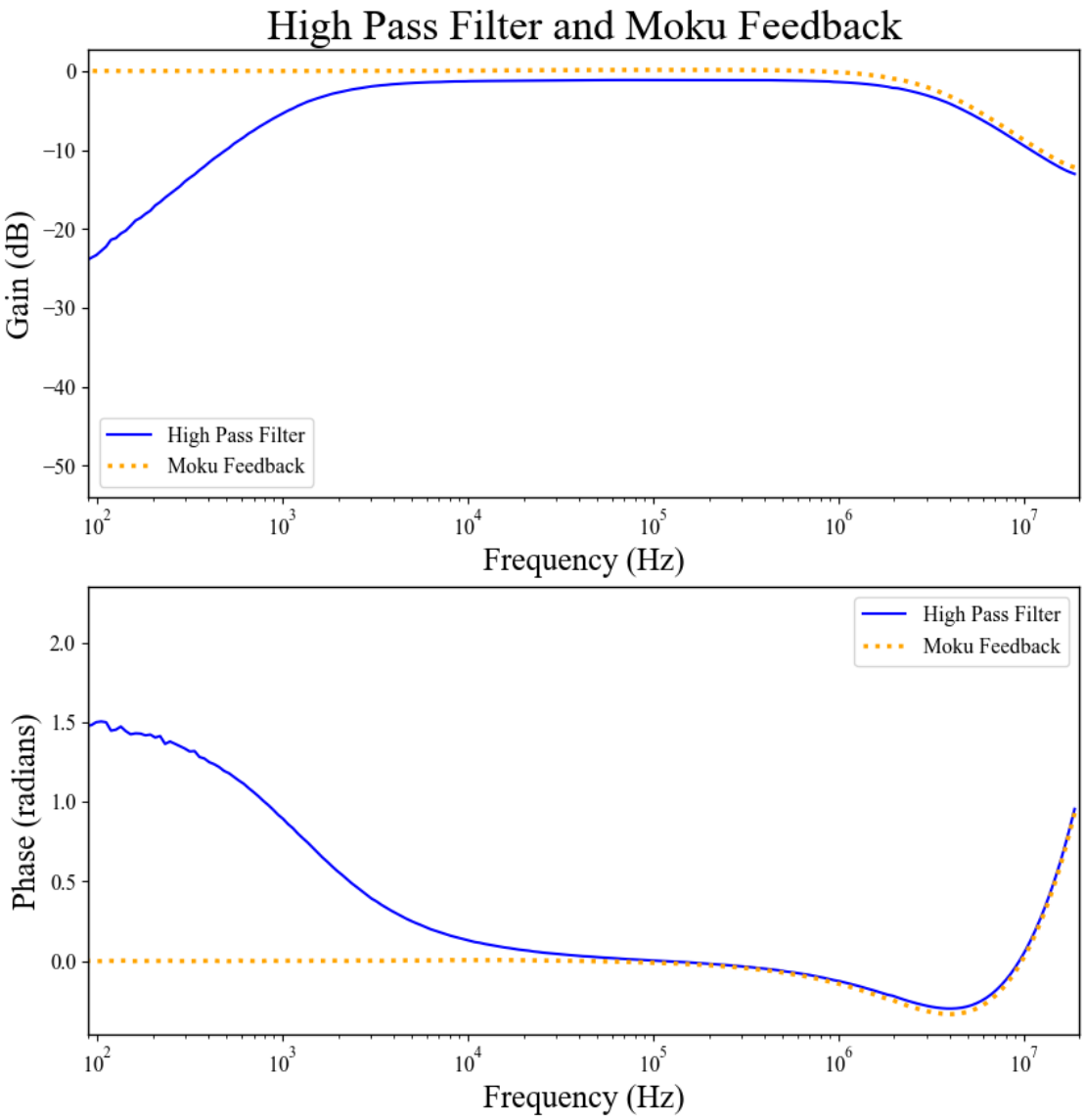


[ ]:
```
def load_data(file):
    data = pd.read_csv(file, delimiter = ',', skiprows = 2)
    data.columns = ['freq','gain','phase']
    data['phase'] = float_array_convert(data['phase'])*(np.pi/180)
    return data

moku_feedback = load_data('data/moku_csv/moku_itself_data.csv')

plt.figure(figsize=(10,10))
plt.subplot(2,1,1)
plt.plot((moku_feedback['freq']),moku_feedback['gain'], label = 'Experimental',␣
 ↪color = 'blue')
```

```
plt.xlabel('Frequency (Hz)')
plt.xscale('log')
plt.ylabel('Gain (dB)')
plt.title('Moku Feedback')
plt.legend()
plt.subplot(2,1,2)
plt.plot((moku_feedback['freq']),moku_feedback['phase'], label =␣
 ↪'Experimental', color = 'blue')
plt.xlabel('Frequency (Hz)')
plt.xscale('log')
plt.ylabel('Phase (radians)')
plt.legend()
plt.show()
```

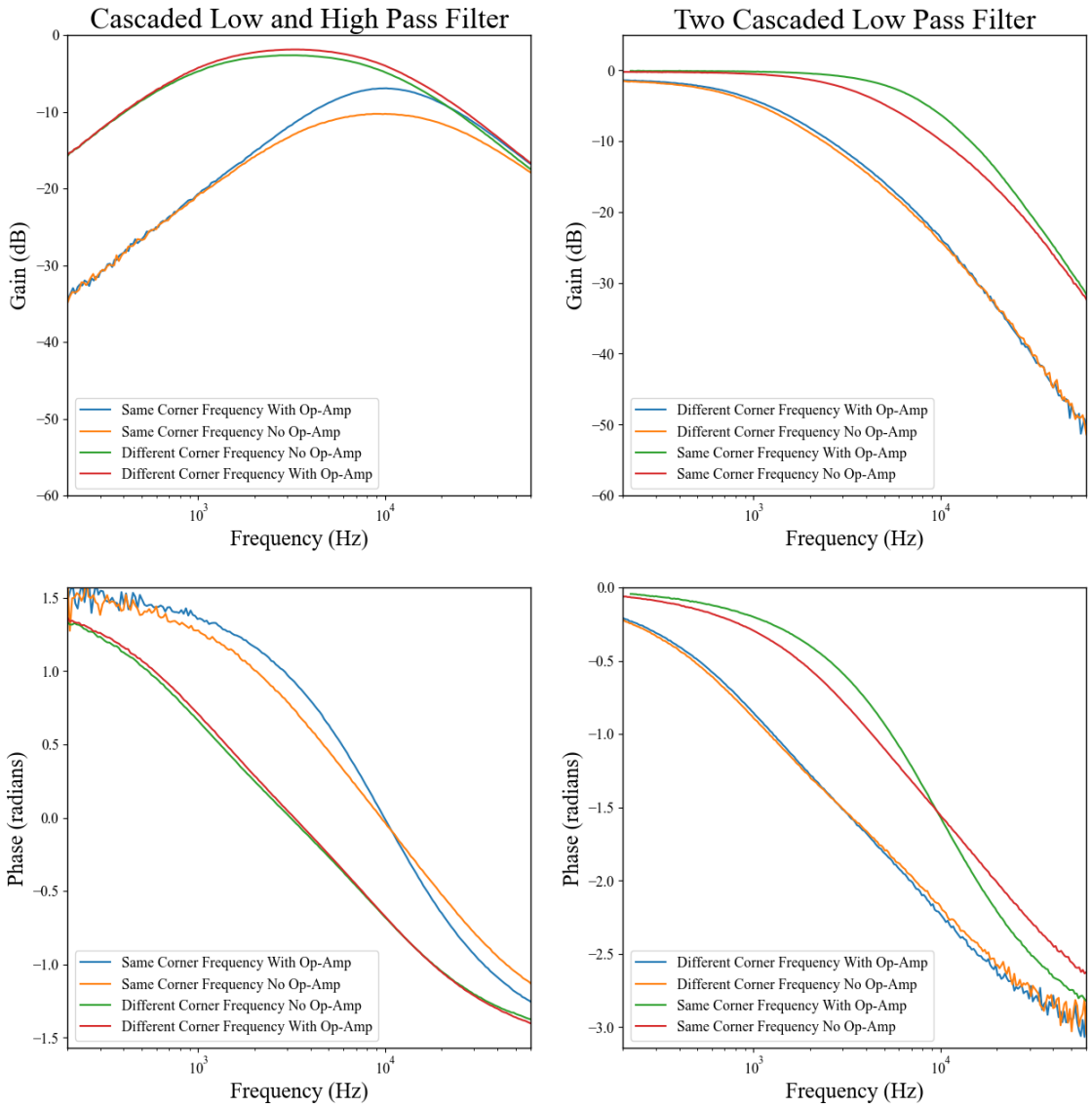


[ ]:
```
hp_freq_res = load_data('data/moku_csv/HP_freq_res_data.csv')

plt.figure(figsize=(10,10))
plt.subplot(2,1,1)
plt.plot((hp_freq_res['freq']),hp_freq_res['gain'], label = 'High Pass Filter',␣
 ↪color = 'blue')
plt.plot((moku_feedback['freq']),moku_feedback['gain'], label = 'Moku␣
 ↪Feedback', color = 'orange', linestyle = ':', linewidth = 2.5)
plt.xlabel('Frequency (Hz)')
plt.xscale('log')
plt.xlim(9e1,2e7)
plt.ylabel('Gain (dB)')
plt.title('High Pass Filter and Moku Feedback')
plt.legend()
plt.subplot(2,1,2)
plt.plot((hp_freq_res['freq']),hp_freq_res['phase'], label = 'High Pass␣
 ↪Filter', color = 'blue')
plt.plot((moku_feedback['freq']),moku_feedback['phase'], label = 'Moku␣
 ↪Feedback', color = 'orange', linestyle = ':', linewidth = 2.5)
plt.xlabel('Frequency (Hz)')
plt.xscale('log')
plt.xlim(9e1,2e7)
plt.ylabel('Phase (radians)')
plt.legend()
plt.show()
```



[ ]:
```
Path = 'data/moku_csv/'
plt.figure(figsize=(15,15))
files = os.listdir(Path)

for file in files:
    if re.search('high',file):

        data = load_data(Path+file)
        labels = (pd.read_csv(Path+file,nrows = 0)).columns[0]

        plt.subplot(2,2,1)
        plt.plot((data['freq']),data['gain'], label = labels)
```

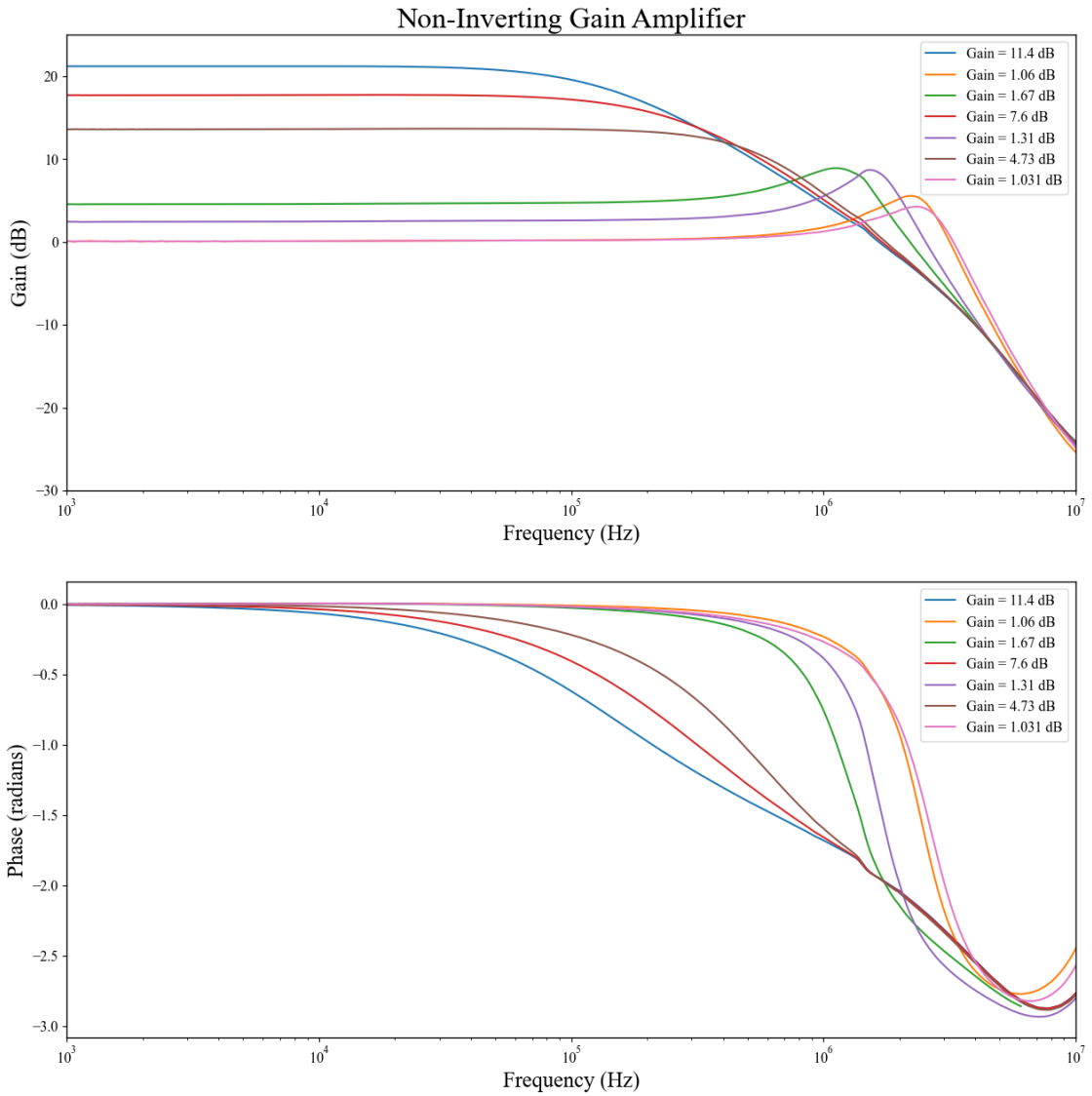
```
        plt.xlabel('Frequency (Hz)')
        plt.xscale('log')
        plt.xlim(2e2,6e4)
        plt.ylim(-60,0)
        plt.ylabel('Gain (dB)')
        plt.title('Cascaded Low and High Pass Filter')
        plt.legend()
        plt.subplot(2,2,3)
        plt.plot((data['freq']),data['phase'], label = labels)
        plt.xlabel('Frequency (Hz)')
        plt.xscale('log')
        plt.xlim(2e2,6e4)
        plt.ylim(-np.pi/2,np.pi/2)
        plt.ylabel('Phase (radians)')
        plt.legend()


    elif file.startswith('casc_lowpass'):

        data = load_data(Path+file)
        labels = (pd.read_csv(Path+file,nrows = 0)).columns[0]

        plt.subplot(2,2,2)
        plt.plot((data['freq']),data['gain'], label = labels)
        plt.xlabel('Frequency (Hz)')
        plt.xscale('log')
        plt.xlim(2e2,6e4)
        plt.ylim(-60,5)
        plt.ylabel('Gain (dB)')
        plt.title('Two Cascaded Low Pass Filter')
        plt.legend()
        plt.subplot(2,2,4)
        plt.plot((data['freq']),data['phase'],label = labels)
        plt.xlabel('Frequency (Hz)')
        plt.xscale('log')
        plt.xlim(2e2,6e4)
        plt.ylim(-np.pi,0)
        plt.ylabel('Phase (radians)')
        plt.legend()
plt.show()
```

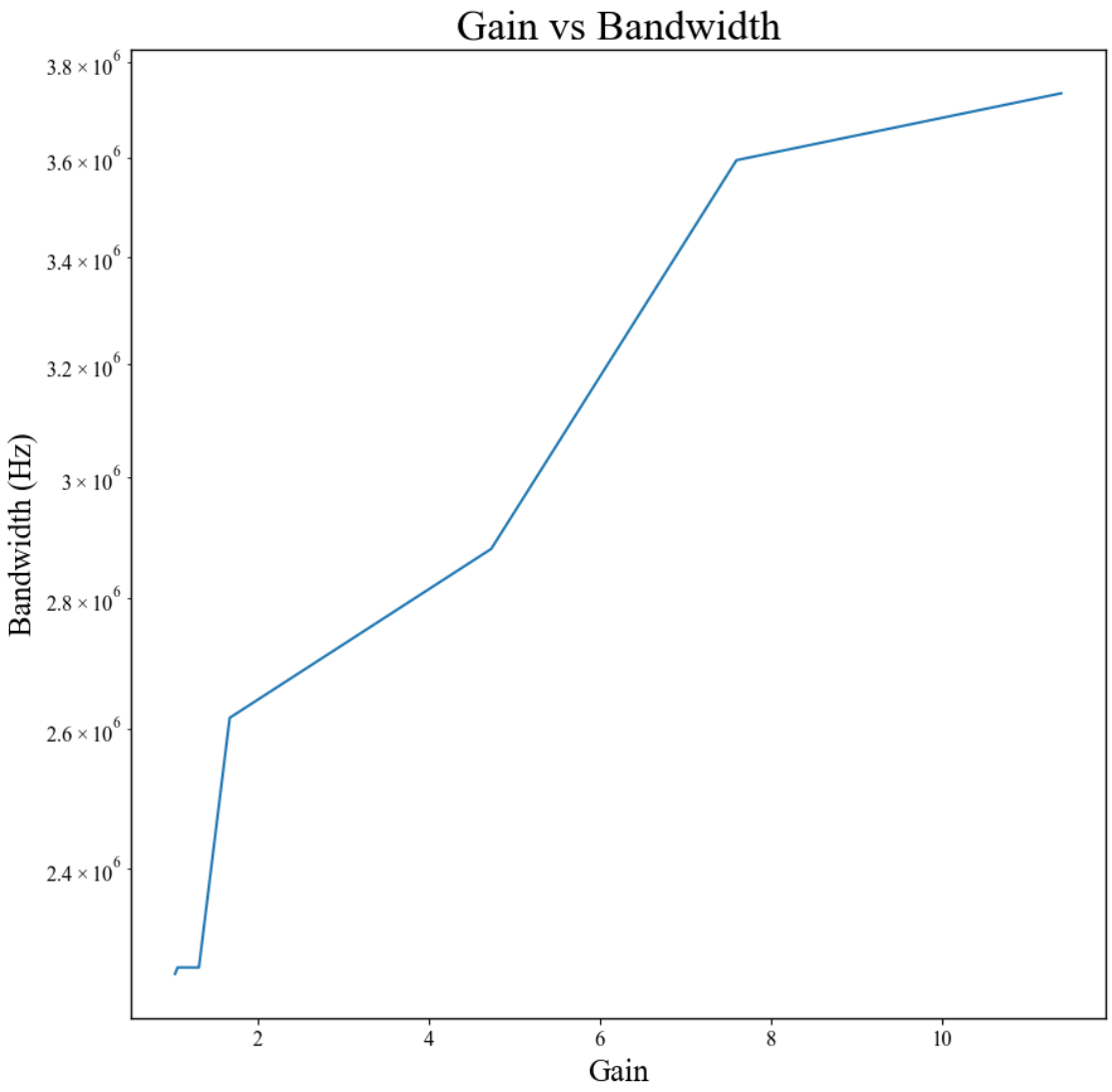


[ ]:
```
plt.figure(figsize=(15,15))
files = os.listdir(Path)

for file in files:
    if file.startswith('non'):

        data = load_data(Path+file)
        labels = (pd.read_csv(Path+file,nrows = 0)).columns[0]

        plt.subplot(2,1,1)
        plt.plot((data['freq']),data['gain'], label = labels)
        plt.xlabel('Frequency (Hz)')
```

```
        plt.xscale('log')
        plt.xlim(1e3,1e7)
        plt.ylim(-30,25)
        plt.ylabel('Gain (dB)')
        plt.title('Non-Inverting Gain Amplifier')
        plt.legend()
        plt.subplot(2,1,2)
        plt.plot((data['freq']),data['phase'], label = labels)
        plt.xlabel('Frequency (Hz)')
        plt.xlim(1e3,1e7)

        plt.xscale('log')
        plt.ylabel('Phase (radians)')
        plt.legend()

def bandwidth_calc(data):
    return data['freq'][np.argmin(np.abs(data['gain']+3))]
bandwidth = []
gain = [11.4,1.06,1.67,7.6,1.31,4.73,1.031]
for file in files:
    if file.startswith('non'):
        data = load_data(Path+file)
        bandwidth.append(bandwidth_calc(data))
print(bandwidth)
print(gain)
plt.figure(figsize=(10,10))
plt.plot(np.sort(gain),np.sort(bandwidth))
plt.xlabel('Gain')
plt.ylabel('Bandwidth (Hz)')
plt.yscale('log')
plt.title('Gain vs Bandwidth')
plt.show()
```

```
[2260380.18, 3594345.1, 2615539.95, 2268586.01, 2879962.82, 2268586.01,
3734087.1]
[11.4, 1.06, 1.67, 7.6, 1.31, 4.73, 1.031]
```


Non-Inverting Gain Amplifier
Gain (dB)
Frequency (Hz)
Phase (radians)
Frequency (Hz)
Gain = 11.4 dB
Gain = 1.06 dB
Gain = 1.67 dB
Gain = 7.6 dB
Gain = 1.31 dB
Gain = 4.73 dB
Gain = 1.031 dB


Gain vs Bandwidth
Bandwidth (Hz)
3.8 × 10^6
3.6 × 10^6
3.4 × 10^6
3.2 × 10^6
3 × 10^6
2.8 × 10^6
2.6 × 10^6
2.4 × 10^6
2
4
6
8
10
Gain

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