DSP Basics - Prof Ryan Robucci - This notebook introduces some basic code processes required in the field of DSP

A good reference for getting started with numpy and ploting
https://www.labri.fr/perso/nrougier/teaching/matplotlib/
(https://www.labri.fr/perso/nrougier/teaching/matplotlib/)

(This is a documentation cell, note I can use latex: ω)

The cell below contains the function zplane which is not commonly included with python packages

To use it your own code you can download the file

- https://bitbucket.org/cfelton/examples/raw/f3383e14f18a57852e17c10ee4cd316fbfafbf85/snip
  (https://bitbucket.org/cfelton/examples/raw/f3383e14f18a57852e17c10ee4cd316fbfafbf85/sni

Then use the following import in your pyton code:

- from plot_zplane import zplane

In [1]:
```python
#
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#

# The following is derived from the slides presented by
# Alexander Kain for CS506/606 "Special Topics: Speech Signal Processing"
# CSLU / OHSU, Spring Term 2011.
#
# 2017/03/04 Ryan Robucci - changed plot raduis to expand to 10% beyond largest

import numpy as np
import matplotlib.pyplot as plt
from  matplotlib import patches
from matplotlib.figure import Figure
from matplotlib import rcParams

def zplane(b,a,filename=None):
    """Plot the complex z-plane given a transfer function.
    """

    # get a figure/plot
    ax = plt.subplot(111)

    # create the unit circle
    uc = patches.Circle((0,0), radius=1, fill=False,
                        color='black', ls='dashed')
    ax.add_patch(uc)

    # The coefficients are less than 1, normalize the coeficients
    if np.max(b) > 1:
        kn = np.max(b)
        b = b/float(kn)
    else:
        kn = 1

    if np.max(a) > 1:
        kd = np.max(a)
        a = a/float(kd)
    else:
        kd = 1

    # Get the poles and zeros
    p = np.roots(a)
    z = np.roots(b)
```

```python
    k = kn/float(kd)

    # Plot the zeros and set marker properties
    t1 = plt.plot(z.real, z.imag, 'go', ms=10)
    plt.setp( t1, markersize=10.0, markeredgewidth=1.0,
              markeredgecolor='k', markerfacecolor='g')

    # Plot the poles and set marker properties
    t2 = plt.plot(p.real, p.imag, 'rx', ms=10)
    plt.setp( t2, markersize=12.0, markeredgewidth=3.0,
              markeredgecolor='r', markerfacecolor='r')

    ax.spines['left'].set_position('center')
    ax.spines['bottom'].set_position('center')
    ax.spines['right'].set_visible(False)
    ax.spines['top'].set_visible(False)

    # set the ticks
    #RWR: the following has been modified to fit larger-magnitude roots and mar
    r = 1.1*max(1.5/1.1,np.abs(np.concatenate((p.real,p.imag,z.real,z.imag))).m
    plt.axis('scaled');
    if r<1.6:
        ticks = [-1, -.5, .5, 1];
    elif r<5:
        ticks = [-2,-1, -.5, .5, 1,2];
    elif r<10:
        ticks = [-5,-2,-1,1,2,5];
    elif r<20:
        ticks = [-10,-1,1,10];
    else:
        rlog = np.ceil(np.log10(r))
        ticks = np.arange(-(10**rlog),(10**rlog)+1,10**(rlog-1)*2);

    plt.xticks(ticks);
    plt.yticks(ticks)
    plt.axis([-r, r, -r, r])

    if filename is None:
        plt.show()
    else:
        plt.savefig(filename)


    return z, p, k
```

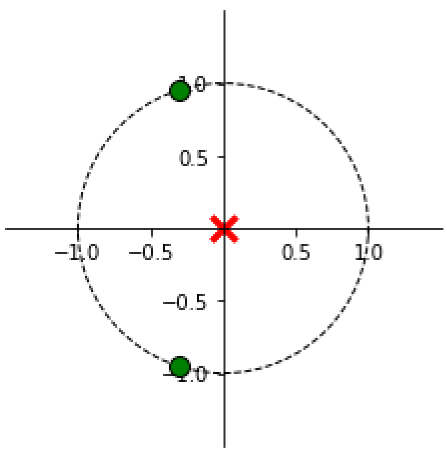
$$\mathcal{Z}^{-1}\left\{1 + z^{-}1 + z^{-}2 + z^{-}3\right\} = \delta[n] + 2\delta[n-1] + 2\delta[n-2] + \delta[n-3]$$

In [13]:
```
import numpy as np
#             z^-2 + 0.618z^-1+1
# H(z)=  --------------------
#          2.618
b = np.array([1,0.618,1])
b=b/sum(b)
a = np.array([1, 0, 0])
```

In [36]:
```
[z,p,g] = signal.tf2zpk(b, a)
print('P:',p)
print('Z:',z)
print('G:',g)
[b,a] = signal.zpk2tf(z, p*10, g)
print('b:',b)
print('a:',a)
```

```
P: [0. 0.]
Z: [-0.309+0.95106204j -0.309-0.95106204j]
G: 0.38197097020626436
b: [0.38197097 0.23605806 0.38197097]
a: [1. 0. 0.]
```

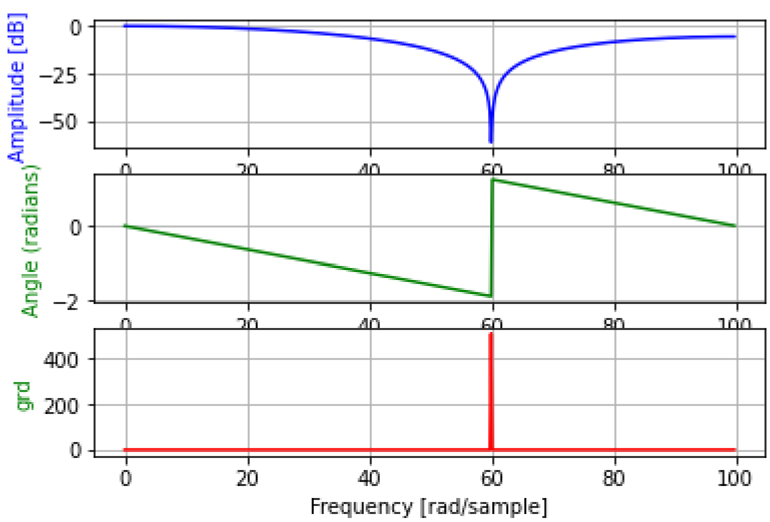
In [37]:
```
zplane(b,a)
plt.show()
```



In [15]:
```
from scipy import signal #https://docs.scipy.org/doc/scipy-0.18.1/reference/sig
```

In [28]:
```
w, H = signal.freqz(b,a)
fs=200
ww=(fs*w)/(2*np.pi)
```

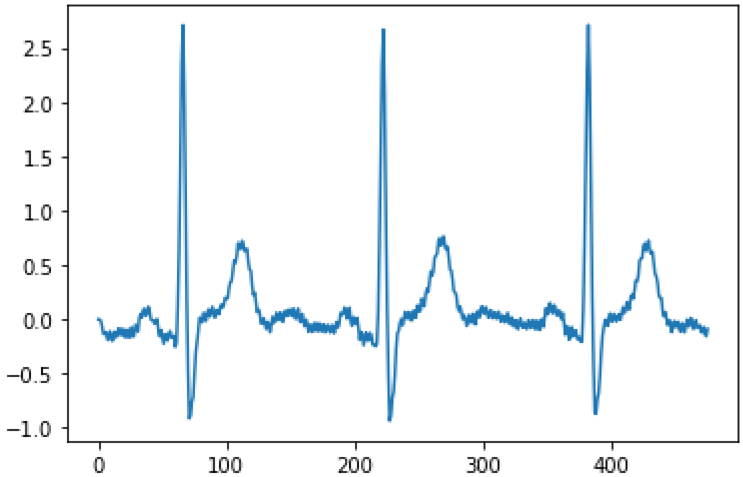
In [29]:
```
import matplotlib.pyplot as plt
plt.subplot(311)
plt.plot(ww, 20 * np.log10(np.abs(H)), 'b')
plt.ylabel('Amplitude [dB]', color='b')
plt.xlabel('Frequency [rad/sample]')
plt.grid(True)
plt.axis('tight')
plt.subplot(312)
angles = np.unwrap(np.angle(H))
plt.plot(ww, angles, 'g')
plt.ylabel('Angle (radians)', color='g')
plt.xlabel('Frequency [rad/sample]')
plt.grid(True)
plt.axis('tight')

plt.subplot(313)
grd = np.diff(angles)/np.diff(w)
grd_temp=np.append(grd,0)
plt.plot(ww, grd_temp, 'r')
plt.ylabel('grd', color='g')
plt.xlabel('Frequency [rad/sample]')
plt.grid(True)
plt.axis('tight')
plt.show()
```



In [45]:
```
ecg = np.genfromtxt('ecg2x60.dat')
```

In [47]:
```python
plt.plot(ecg)
```

Out[47]:
```
[<matplotlib.lines.Line2D at 0x20eb25d9d60>]
```



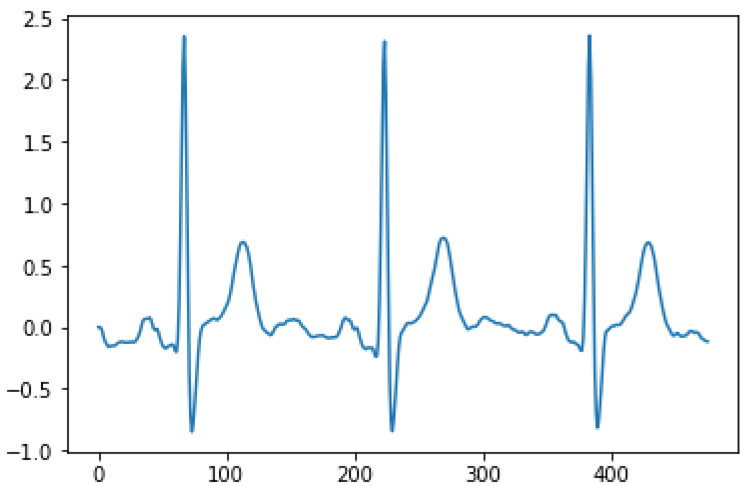
Note the "group" or "range" of freqeuncies with a localized, generalized linear delay

What group delay does it correspond to?

In [48]:
```python
filtered_ecg = signal.lfilter(b,a,ecg)
```

In [49]:
```python
plt.plot(filtered_ecg)
```

Out[49]:
```
[<matplotlib.lines.Line2D at 0x20eb23fe670>]
```

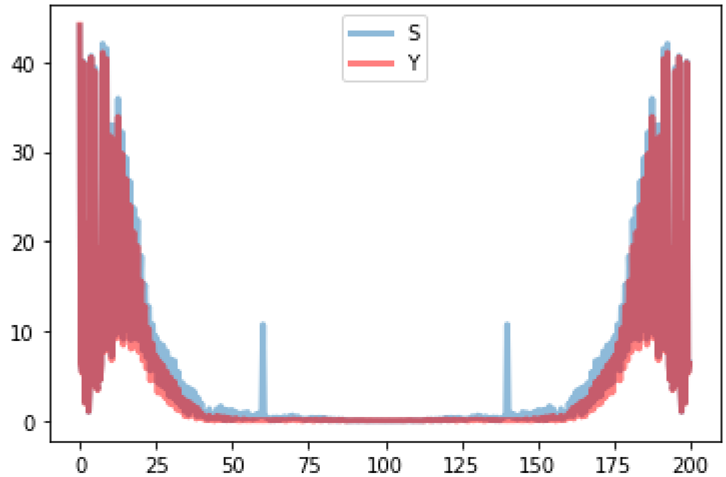


In [50]:
```python
import numpy as np
S = np.fft.fft(ecg) # https://docs.scipy.org/doc/numpy/reference/routines.fft.h
Y = np.fft.fft(filtered_ecg)
```

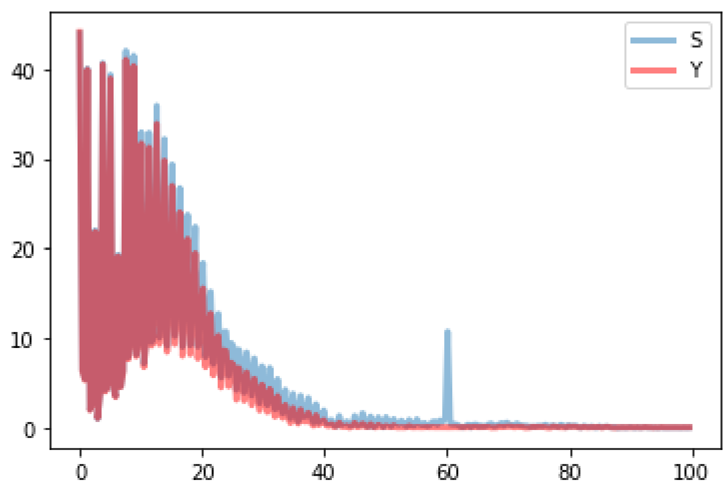
In [58]:
```python
len(omega)
```

Out[58]: 476

In [65]:
```
dF = fs/476;
f = np.arange(-fs/2,(fs/2),dF);
plt.plot(f+fs/2,np.abs(S), label = 'S',linewidth=3,alpha=.5) # in matlab extra
plt.plot(f+fs/2,np.abs(Y), label = 'Y',linewidth=3,alpha=.5,color='r')
plt.legend()
plt.axis('tight')
plt.show()
```



In [59]:
```
omega = 2 * np.pi * np.arange(len(S))/len(S)
omega=(omega*fs)/(2 * np.pi)
plt.plot(omega[0:int(476/2)],np.abs(S[0:int(476/2)]), label = 'S',linewidth=3,a
plt.plot(omega[0:int(476/2)],np.abs(Y[0:int(476/2)]), label = 'Y',linewidth=3,a
plt.legend()
plt.axis('tight')
plt.show()
```



In [68]:
```
Eecg=np.sum(ecg**2)
Eecg
```

Out[68]: 94.49460053477425

In [69]:
```
Efiltecg=np.sum(filtered_ecg**2)
Efiltecg
```
Out[69]:
```
83.42150042053937
```
In [77]:
```
snr=np.log(Eecg/Efiltecg)
```
In [78]:
```
snr
```
Out[78]:
```
0.12463662072142397
```
Next, we rerun the magnitude plot earlier to verify that the gain at the input frequency is a little above $4\times$

We expect a 1.5 sample group delay, based on the center of mass of the impulse response or the derivative of the phase response