FilterBank

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1 Filter Bank

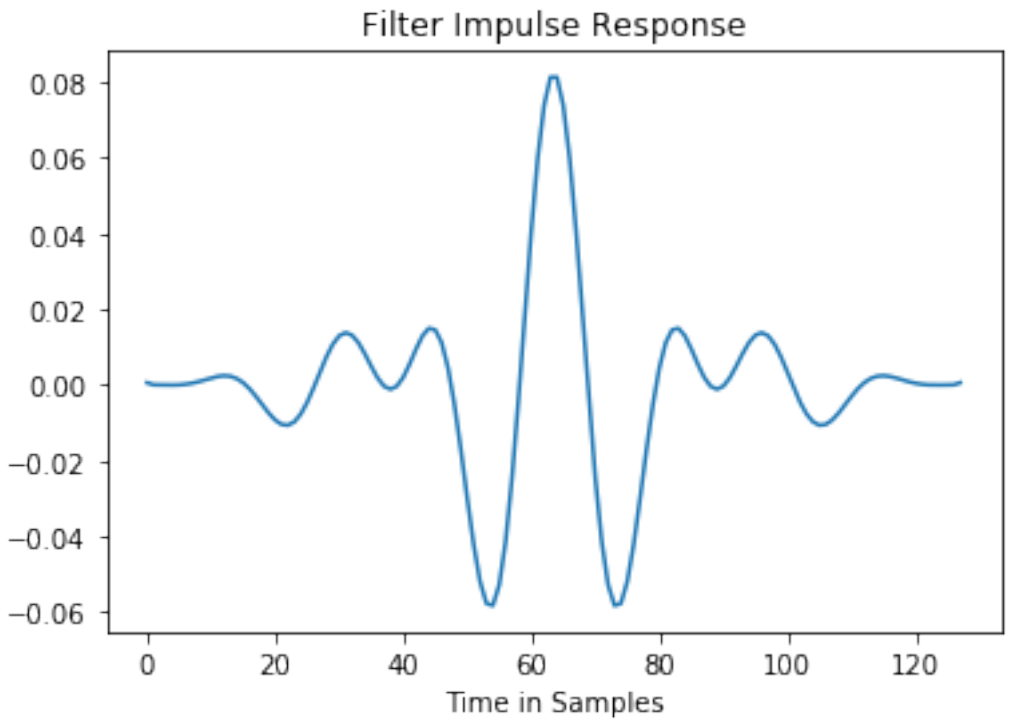
Implement 1 branch, subband k=1, of the analysis and synthesis filter bank with N=16 subbands with 32kHz sampling rate (hence the passband is between 1 kHz and 2 kHz), in **direct implementation**. Start with designing a bandpass filter using the scipy.signal.remez function, which is an "equi-ripple" FIR filter design function:

1.1 Import the modules:

```
In [1]: %matplotlib inline
        import numpy as np
        import scipy.signal as signal
        import matplotlib.pyplot as plt

        N = 16
        b = signal.remez(8*N,[0,500,1000,2000,2500,16000],[0,1,0],[100,1,100],Hz=32000, type='ba
```

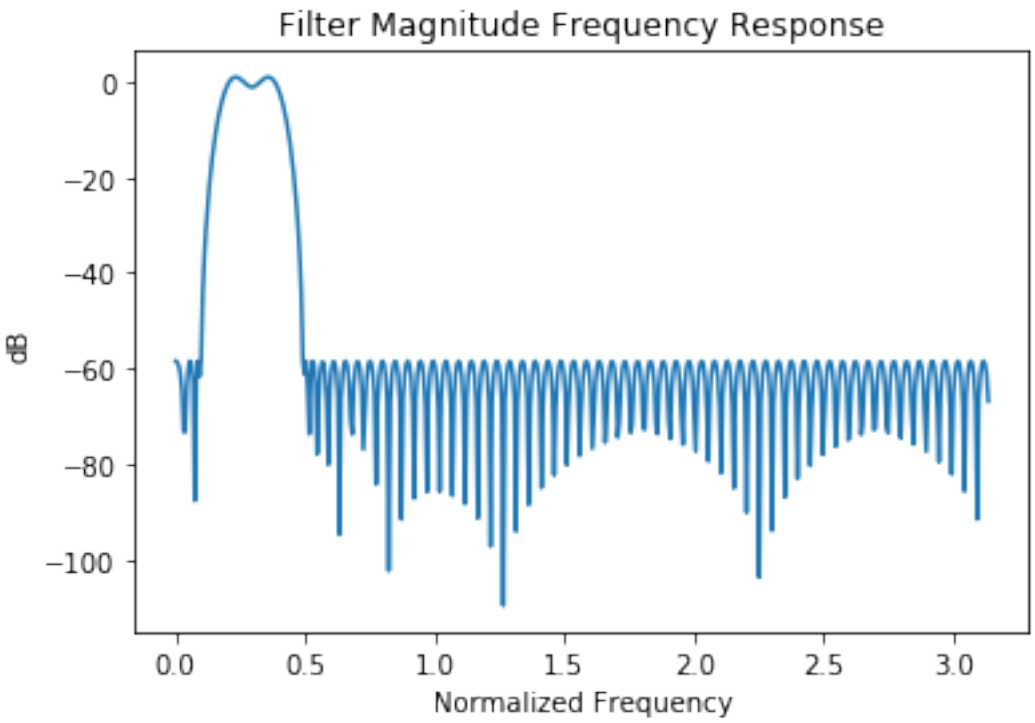
1.2 Check the filter Design:

```
In [2]: plt.plot(b)
        plt.title('Filter Impulse Response')
        plt.xlabel('Time in Samples')

Out[2]: <matplotlib.text.Text at 0x7fefe1ead2d0>
```



1.3 Check the frquency response:

```
In [3]: w,H = signal.freqz(b)
        plt.plot(w, 20*np.log10(abs(H)+1e-6))
        plt.title('Filter Magnitude Frequency Response')
        plt.xlabel('Normalized Frequency')
        plt.ylabel('dB')

Out[3]: <matplotlib.text.Text at 0x7fefe1d5d490>
```

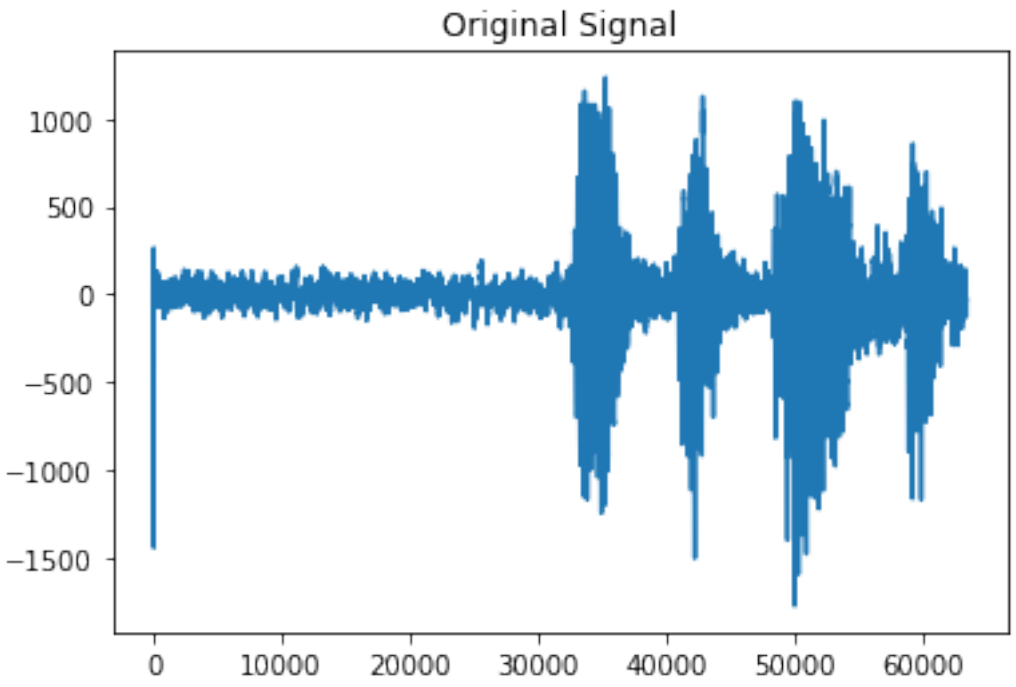


1.4 Now the analysis filtering and down sampling:

```
In [4]: import sound as snd
        [s,rate] = snd.wavread('sndfile.wav')
        print("length of sound in samples: ", len(s))
        plt.plot(s)
        plt.title('Original Signal')
```

```
('Number of channels: ', 1)
('Number of bytes per sample:', 2)
('Sampling rate: ', 32000)
('Number of samples:', 63488)
('length of sound in samples: ', 63488)
```

```
Out[4]: <matplotlib.text.Text at 0x7fefe1164750>
```

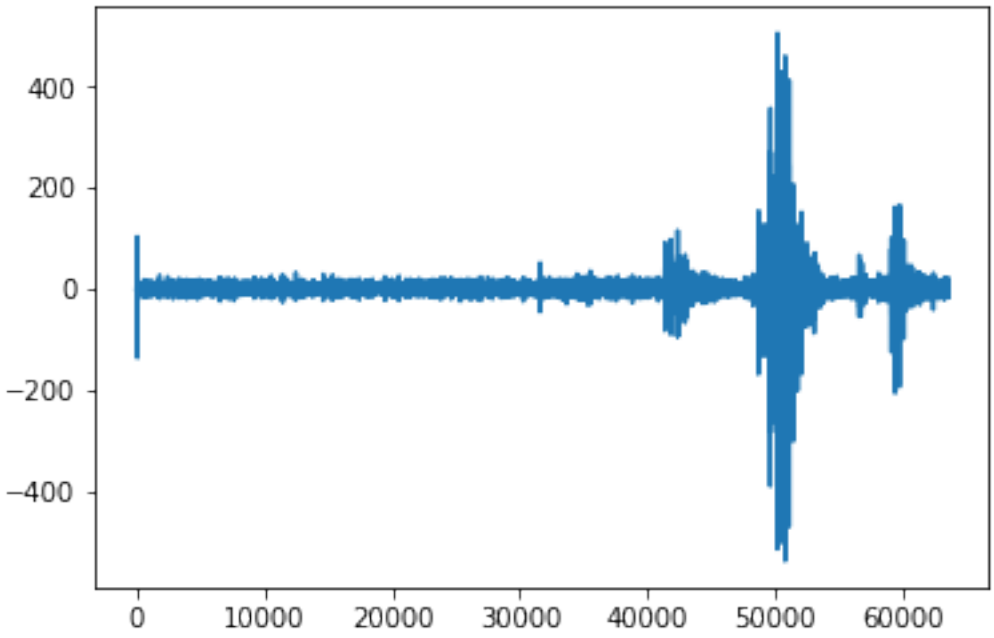


1.5 Filter implementation:

```
In [5]: filtered = signal.lfilter(b,1,s)
        print("length of filtered sound in samples: ", len(filtered))
        plt.plot(filtered)
```

```
('length of filtered sound in samples: ', 63488)
```

```
Out[5]: [<matplotlib.lines.Line2D at 0x7fefe0fe6c90>]
```



1.6 Play the filtered sound:

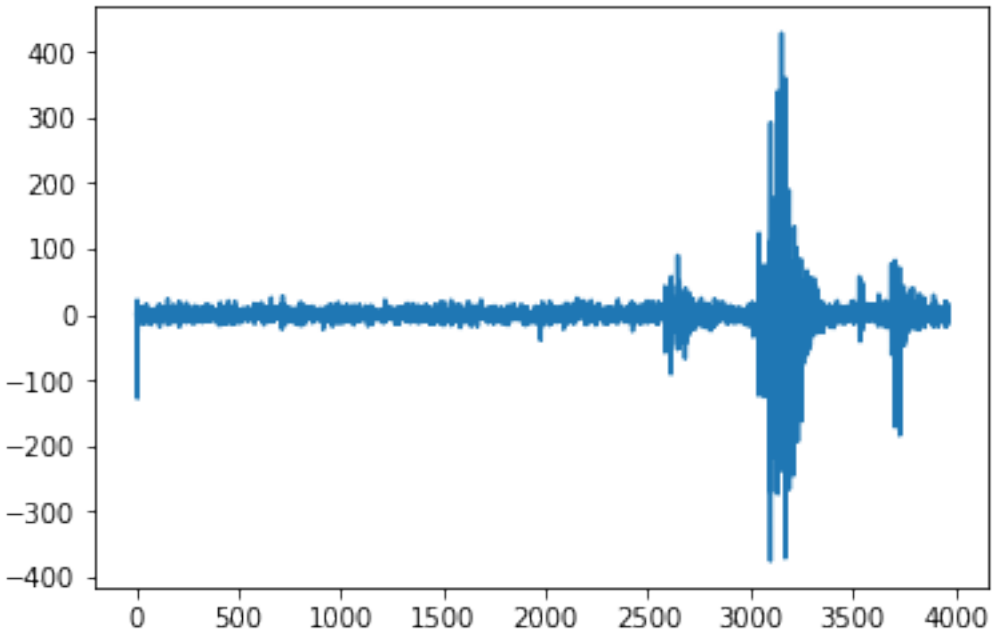
```
In [6]: import functions
        snd.sound(filtered, 32000)
```

```
* done
```

1.7 Now Down-sampling with factor N:

```
In [7]: N=16
        filteredds = filtered[::N]
        plt.plot(filteredds)
```

```
Out[7]: [<matplotlib.lines.Line2D at 0x7fefe03b2210>]
```



1.8 Listen to it at `1/Nth` sampling rate:

```
In [8]: snd.sound(filteredds, 2000)
```

```
* done
```

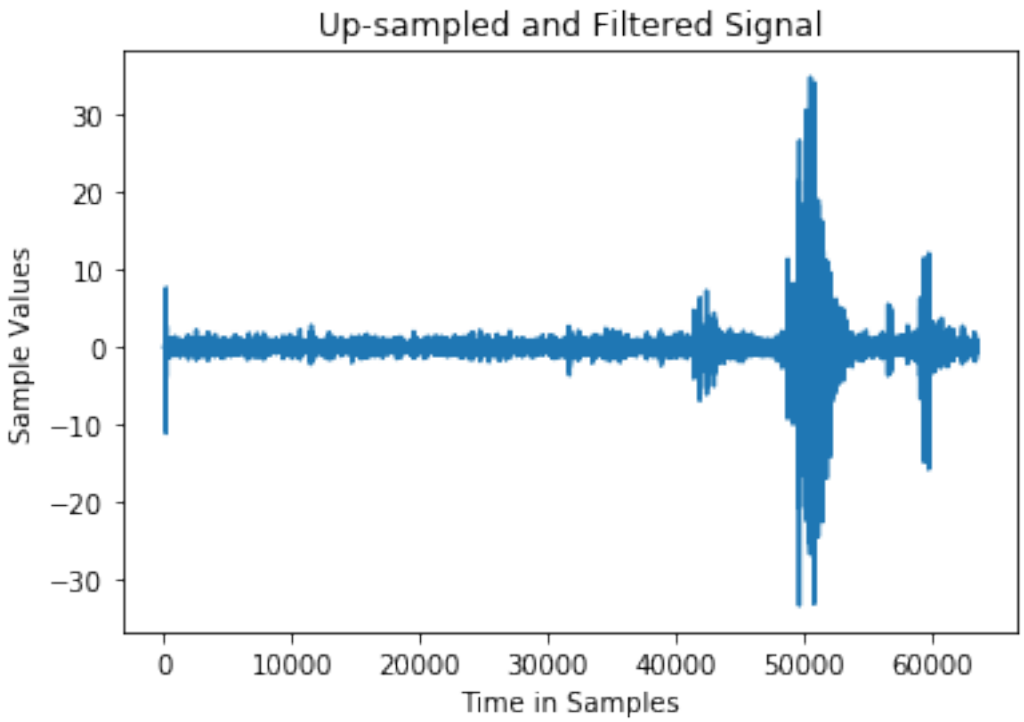
1.9 Now the up-sampling and synthesis filtering:

```
In [9]: #Up-sampling:
        filteredus=np.zeros(len(filteredds)*N)
        filteredus[::N]=filteredds
```

```
In [10]: #Listen to the up-sampled sound:
         snd.sound(filteredus, 32000)
```

```
* done
```

```
In [11]: #Synthesis Filtering:
         #Bandpass Synthesis Filter implementation to attenuate the spectral copies:
         filteredsyn=signal.lfilter(b,1,filteredus)
         plt.plot(filteredsyn)
         plt.title('Up-sampled and Filtered Signal')
         plt.xlabel('Time in Samples')
         plt.ylabel('Sample Values')
         plt.show()
         snd.sound(filteredsyn, 32000)
```


Up-sampled and Filtered Signal
Sample Values
30
20
10
0
−10
−20
−30
0
10000
20000
30000
40000
50000
60000
Time in Samples

```
* done
```