ECG waveform with digital filter- Application of Chebyshev and Moving Average filter.

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Learning objectives:

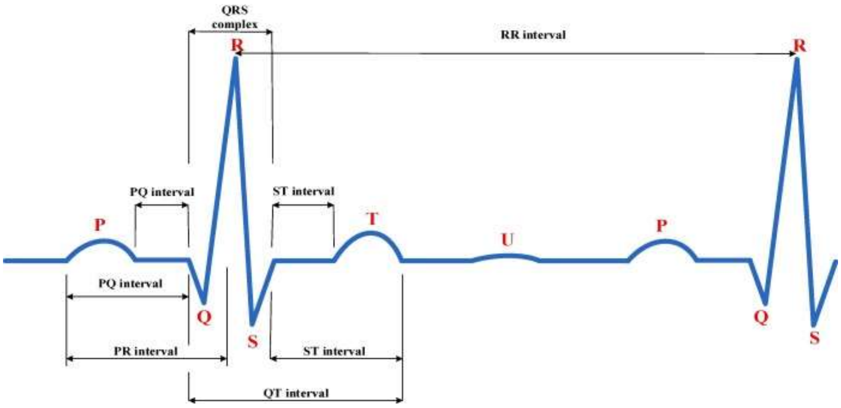
1. **ECG (also called as EKG) signal filtering**
2. **Chebyshev Type II bandstop filter to remove 50Hz noise.**
3. **Chebyshev Type II lowpass filter to filter the high frequency components (above 200Hz)**
4. **Apply Moving average filter to extract the each components of the ECG signal.**

Requirements:

```
1. The data in .csv format is observed using measurement device. It has 8000 samples with 2 seconds time duration.
2. Sampling frequency = 4000Hz = 4kHz.
```

ECG or EKG signal: Bioelectrical signal. Heart's electrical activity represented in terms of the ECG signal.

Picture credit: [https://doi.org/10.1016/j.mehy.2019.109515 (https://doi.org/10.1016/j.mehy.2019.109515)](https://doi.org/10.1016/j.mehy.2019.109515)



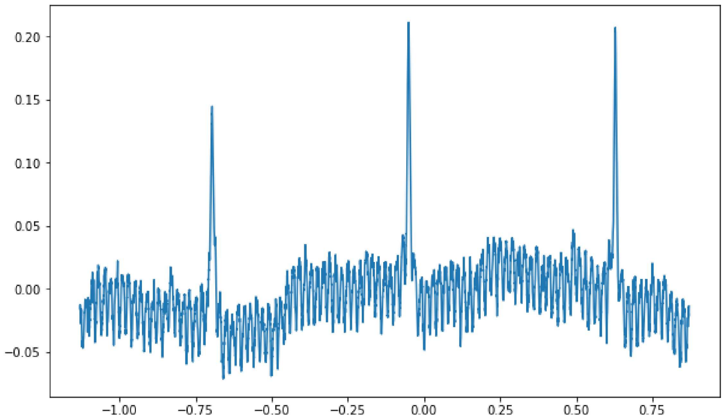
In [49]:
```
# Import the relevant library.

from matplotlib import pyplot as plt
import matplotlib
import pandas as pd
import numpy as np
from scipy.fftpack import fft # For frequency domain represenatation. Fast Fourier transfomation.
from scipy import signal
```

In [50]:
```
# Original data frame and calculation of sampling frequency.

ekgDF = pd.read_csv('ecg.csv') # Original data.
# ekgDF.describe()
# ekgDF.head()
# ekgDF.info

samplingFreq = 1/(ekgDF['Time (s)'][22]-ekgDF['Time (s)'][21])
print ('Sampling frequency = ', samplingFreq, 'Hz')
```

```
Sampling frequency =  3999.9999999986644 Hz
```

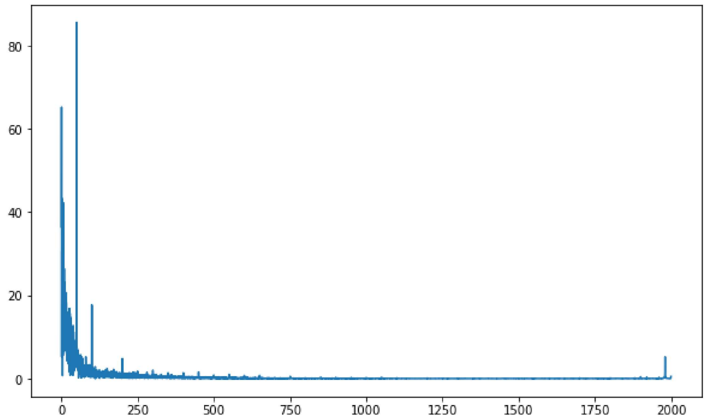
In [51]:
```
# Time Domain representation of the ECG signal.
matplotlib.rc('figure', figsize=(10, 6))
plt.plot(ekgDF['Time (s)'],ekgDF['Channel 1 (V)'])
```

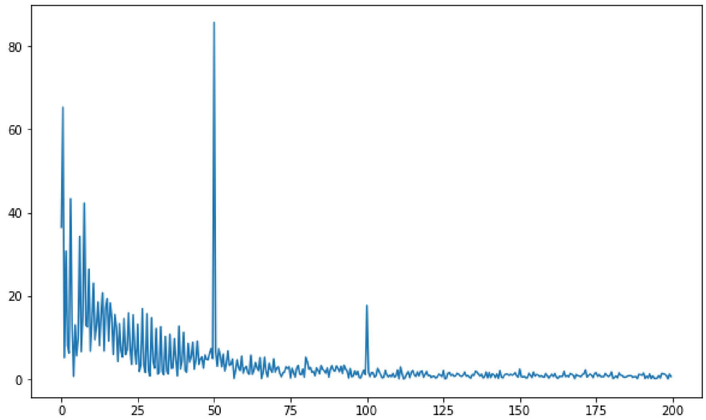
Out[51]: [<matplotlib.lines.Line2D at 0x1c8b44988b0>]



In [52]:
```
# Frequency Domain representation of the ECG signal using FFT on the ECG data.
# According to the Nyquist theorem, the nyquist frequency = maximum frequency to be measured = (sampling frequency)/2
# so, Max frequency components observed on the frequency spectrum = 2000 Hz.
# FFT Len is half size of the length of the signal.

ekgData = ekgDF['Channel 1 (V)'].values # to get the value in array format, not the index.
# len(ekgData)
fftData = np.abs( fft(ekgData) ) # FFT, len(fftData) = 8000
fftLen = int(len(fftData) / 2)  # fftlen = 4000
freqs = np.linspace(0,samplingFreq/2, fftLen ) # len(freqs) = 4000

# Visual representation.
matplotlib.rc('figure', figsize=(10, 6))

plt.figure()
plt.plot( freqs, fftData[0:fftLen] )

plt.figure()
plt.plot( freqs[0:400], fftData[0:400] )

# plt.figure()
# plt.plot( freqs[0:200], fftData[0:200] )
```

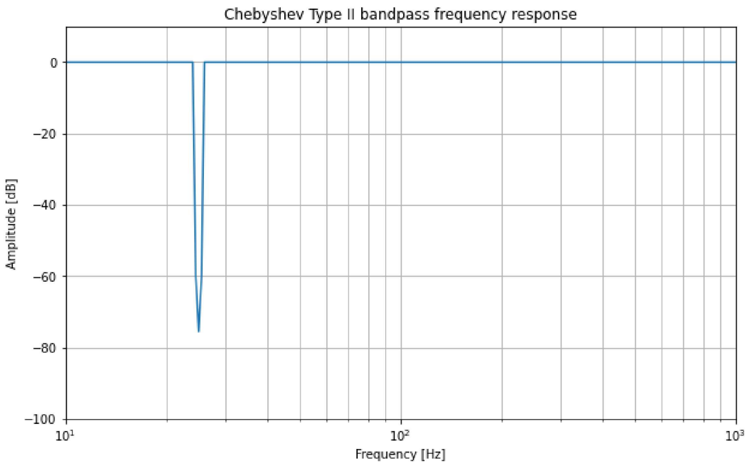
Out[52]:
```
[<matplotlib.lines.Line2D at 0x1c8b452b3a0>]
```





In [ ]:

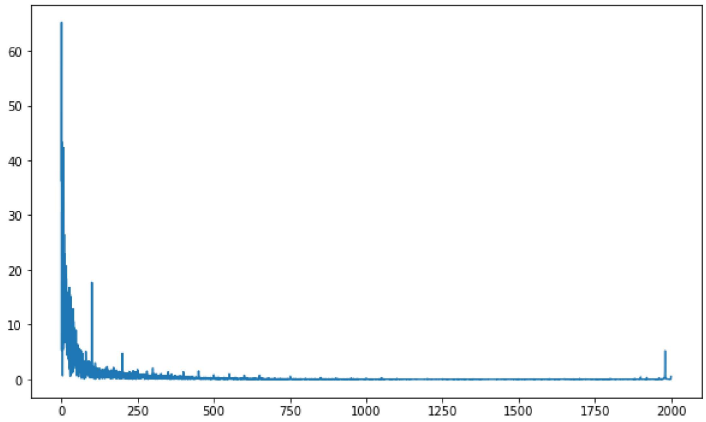
In [53]:
```python
## IIR filter- Chebyshev Type II bandstop filter to filter the high noise seen at 50 Hz in the above signal.
# Chebyshev Type II filter, filter coefficients = 17, gain = -60 dB, frequency stop band = 49 - 51 Hz.

# details of the function iirfilter: https://docs.scipy.org/doc/scipy/reference/generated/scipy.signal.iirfilter.html
# sos = Second-order sections representation of the IIR filter.

sos = signal.iirfilter(17, [49, 51], rs=60, btype='bandstop',
                        analog=False, ftype='cheby2', fs=4000,
                        output='sos')

# Details of the function sosfreqz: https://docs.scipy.org/doc/scipy/reference/generated/scipy.signal.sosfreqz.html
# w = The frequencies at which h was computed
# h = The frequency response, as complex numbers.

w, h = signal.sosfreqz(sos, 2000, fs=2000)

# Plot of the IIR filter.
fig = plt.figure()
ax = fig.add_subplot(1, 1, 1)
ax.semilogx(w, 20 * np.log10(np.maximum(abs(h), 1e-5)))
ax.set_title('Chebyshev Type II bandpass frequency response')
ax.set_xlabel('Frequency [Hz]')
ax.set_ylabel('Amplitude [dB]')
ax.axis((10, 1000, -100, 10))
ax.grid(which='both', axis='both')
plt.show()
```

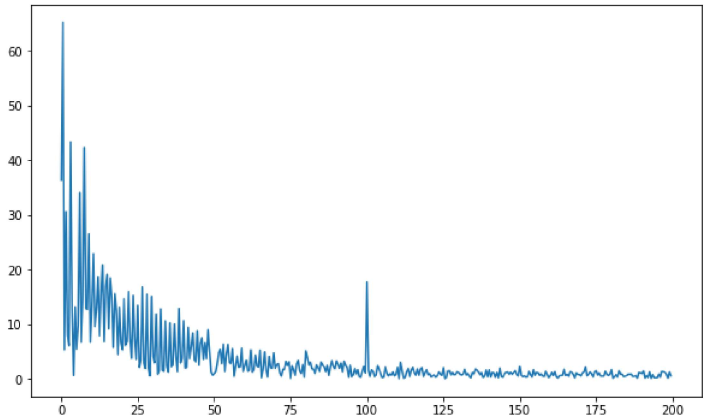


In [54]:
```python
## filtering the noise from the ECG signal at 50 Hz.
# Details of the function: https://docs.scipy.org/doc/scipy/reference/generated/scipy.signal.sosfilt.html

ekgFiltered = signal.sosfilt(sos, ekgData) # Filtering the ECG data with IIR filter.
```

In [55]:
```python
# Frequency Domain Signal after filtering process. Noise removed.
# FFT len is half size of the signal len
# Because of nyquist theorem only half of the sampling frequency can be seen in the sprectrum
fftData = np.abs( fft(ekgFiltered) )
fftLen = int(len(fftData) / 2)
freqs = np.linspace(0,samplingFreq/2, fftLen )

matplotlib.rc('figure', figsize=(10, 6))

plt.figure()
plt.plot( freqs, fftData[0:fftLen] )

plt.figure()
plt.plot( freqs[0:400], fftData[0:400] )
```

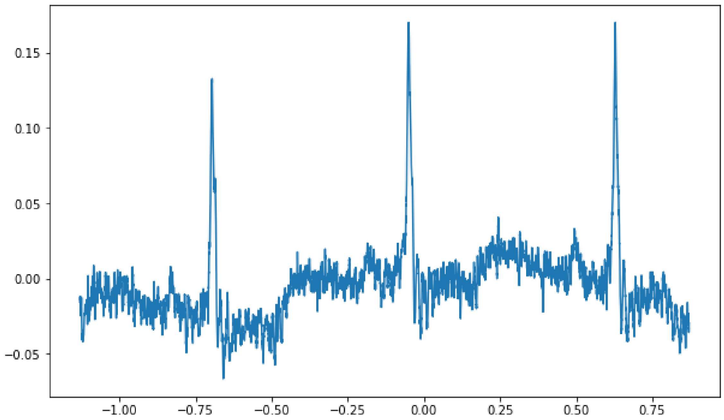
Out[55]: [<matplotlib.lines.Line2D at 0x1c8b7b44d00>]





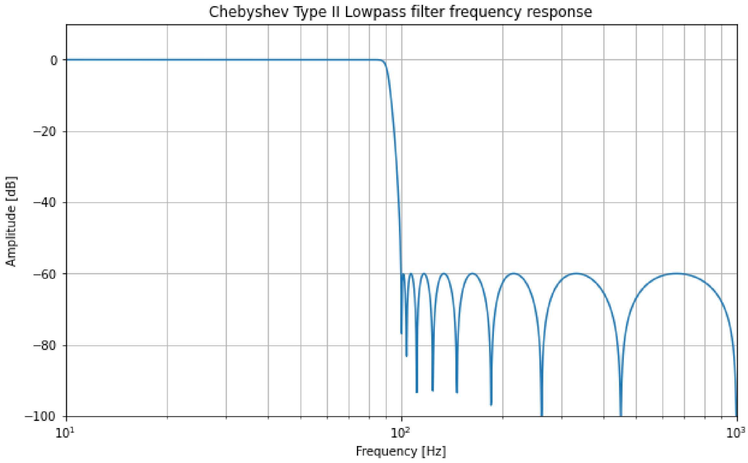
In [56]:
```python
# Time Domain Signal after filtering process. Cleaner signal in comparison to original ECG signal.

matplotlib.rc('figure', figsize=(10, 6))
plt.plot(ekgDF['Time (s)'],ekgFiltered)
```

Out[56]: [<matplotlib.lines.Line2D at 0x1c8b45aed60>]



In [ ]:

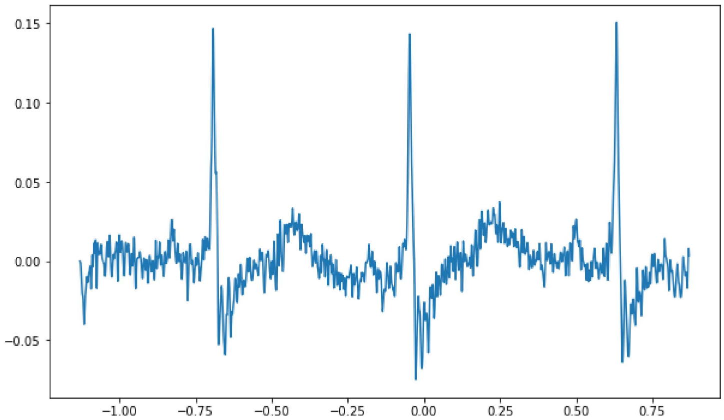
In [57]:
```
# Filter design to remove high-frequency noise components from the signal.
# Chebyshev Type II filter, filter coefficients = 17, gain = -60 dB, Lowpass filter frequency band = 0.5 - 200 Hz.


sos2 = signal.iirfilter(17, [0.5, 200], rs=60, btype='bandpass',
                        analog=False, ftype='cheby2', fs=4000,
                        output='sos')
w, h = signal.sosfreqz(sos2, 2000, fs=2000)
fig = plt.figure()
ax = fig.add_subplot(1, 1, 1)
ax.semilogx(w, 20 * np.log10(np.maximum(abs(h), 1e-5)))
# ax.set_title('Chebyshev Type II bandpass frequency response')
ax.set_title('Chebyshev Type II Lowpass filter frequency response')
ax.set_xlabel('Frequency [Hz]')
ax.set_ylabel('Amplitude [dB]')
ax.axis((10, 1000, -100, 10))
ax.grid(which='both', axis='both')
plt.show()
```



In [58]:
```
## filter out 50 Hz noise
ekgFiltered2 = signal.sosfilt(sos2, ekgFiltered)
```

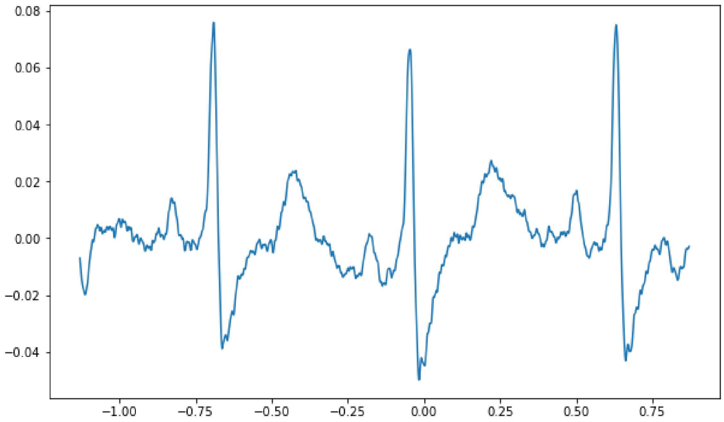
In [59]:
```
# Time Domain Signal
matplotlib.rc('figure', figsize=(10, 6))
plt.plot(ekgDF['Time (s)'],ekgFiltered2)
```

Out[59]: [<matplotlib.lines.Line2D at 0x1c8b45bbcd0>]



In [60]:
```python
# Now after applying moving average filter, we can extract the each components of the ECG signal.

def moving_average(x, w):
    return np.convolve(x, np.ones(w), 'same') / w

# Time Domain Signal
matplotlib.rc('figure', figsize=(10, 6))
plt.plot(ekgDF['Time (s)'],moving_average(ekgFiltered2, 100))
```

Out[60]: [<matplotlib.lines.Line2D at 0x1c8b459cee0>]



In [ ]: