```
% BE 3344       Lab 1 - ECG         03/28/2022

clear
close all
clc

%% 4.7K Ohm Resistor
%Import and plot raw ECG data
data = readmatrix('4.7k_ohmECG.CSV'); %imports data from Excel into a matrix
A = data(:,2); %extracts just the voltage values (col #2)
figure
subplot(2,1,1)
plot(A)
title('Raw ECG Signal - 4.7K Ohm Resistor')
xlabel('Sample Number')
ylabel('Voltage (V)')

%Generate frequency magnitude and phase spectra using FFT
fs = 50000; %sampling frequency (Hz)
L = length(A); %length of signal
y = fft(A);
ds = abs(y/L); %double-sided amplitude spectrum
ss = ds(1:(L/2)+1);
ss(2:end-1) = 2*ss(2:end-1); %single-sided amplitude spectrum
f = (0:L/2)*fs/L; %frequency axis in Hz
subplot(2,1,2)
plot(f,ss)
xlabel('Frequency (Hz)')
ylabel('Amplitude')
title('Single-Sided Amplitude Spectrum - 4.7K Ohm Resistor')

%FIR lowpass filter
fn = fs/2; %Nyquist frequency
fc = 100; %cut-off frequency
n = 50; %filter order
b = fir1(n,fc/fn);
z = filtfilt(b,1,A);
figure
plot(z)
title('FIR Filtered (LP) ECG Signal - 4.7K Ohm Resistor')

%{
%FIR bandpass filter
fc_L = 50; %lower bound cut-off frequency (Hz)
fc_H = 400; %upper bound cut-off frequency (Hz)
b1 = fir1(n,[(fc_L/fn) (fc_H/fn)]);
z1 = filtfilt(b1,1,A); %zero-phase filtering
figure
plot(z1)
title('FIR Filtered (BP) ECG Signal - 4.7K Ohm Resistor')
%}

%Detect R peaks
```

```
[pk,x] = findpeaks(z,'MinPeakHeight',0.15); %finds all peaks w/ amplitudes >=0.16 V; stores the
hold on
plot(x,pk,'ro')

%Computing heart rate
%Method 1
hb = length(pk); %total # of R peaks = # of heart beats
ts = L/fs; % total # of samples/sampling rate (samples/sec) = time in seconds
tm = ts/60; % total time in minutes
bpm1 = hb/tm %heart rate (beats per minute)
```

```
bpm1 = 3.6621e+03
```

```
%Method 2
ts = (x(2)-x(1))/fs; %time interval b/w 2 adjacent R peaks (sec)
tm = ts/60; %time interval in minutes
bpm2 = length(pk)/tm %heart rate (beats per minute)
```

```
bpm2 = 5.4022e+04
```

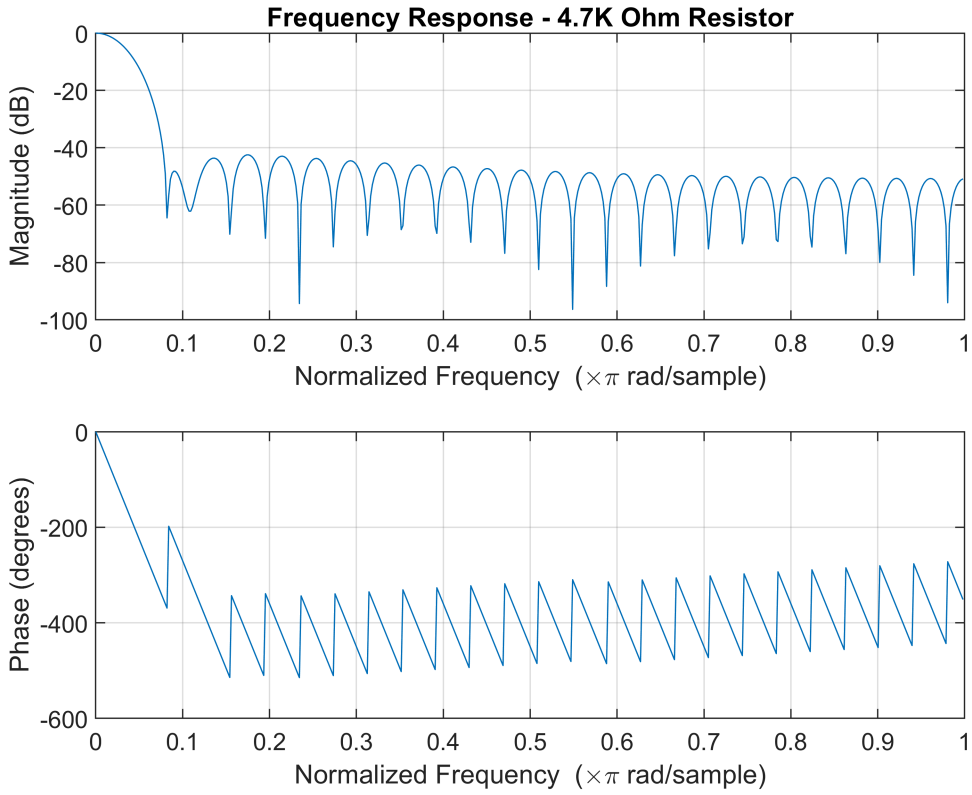
```
%Method 3
trr=x(2)-x(1)
```

```
trr = 833
```

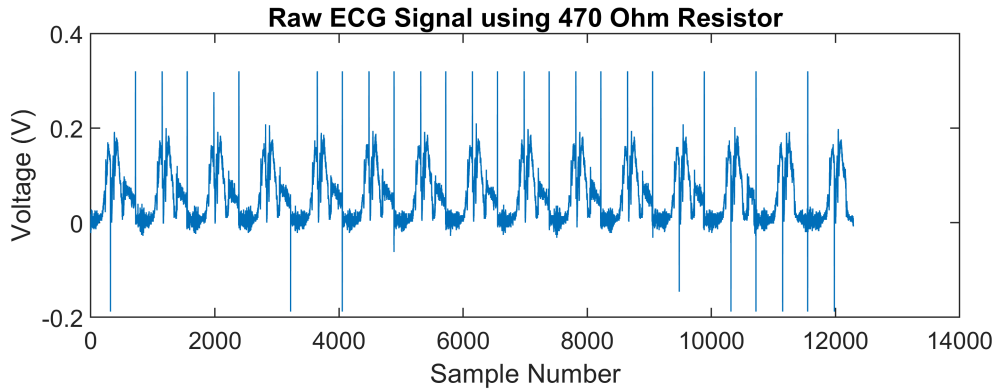
```
bpm3=1/(trr*10^(-3))*60
```

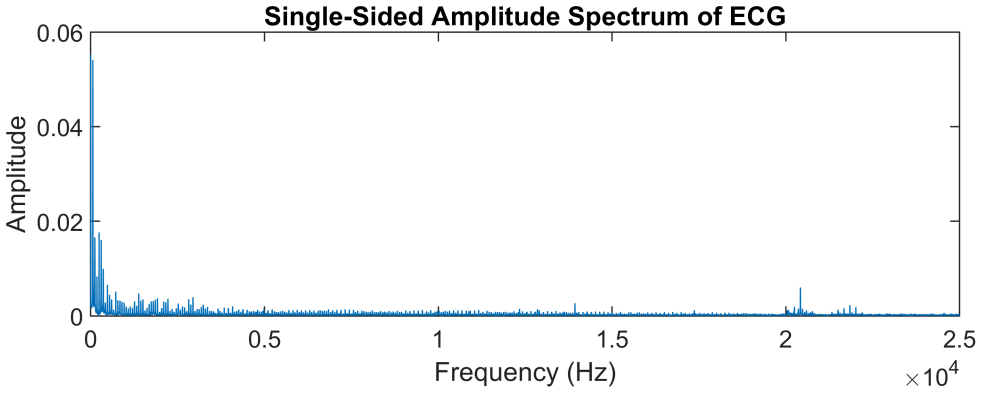
```
bpm3 = 72.0288
```

```
%Frequency and phase response of lowpass FIR filter
figure
subplot(2,1,1)
freqz(b) %frequency response
title('Frequency Response - 4.7K Ohm Resistor')
subplot(2,1,2)
```

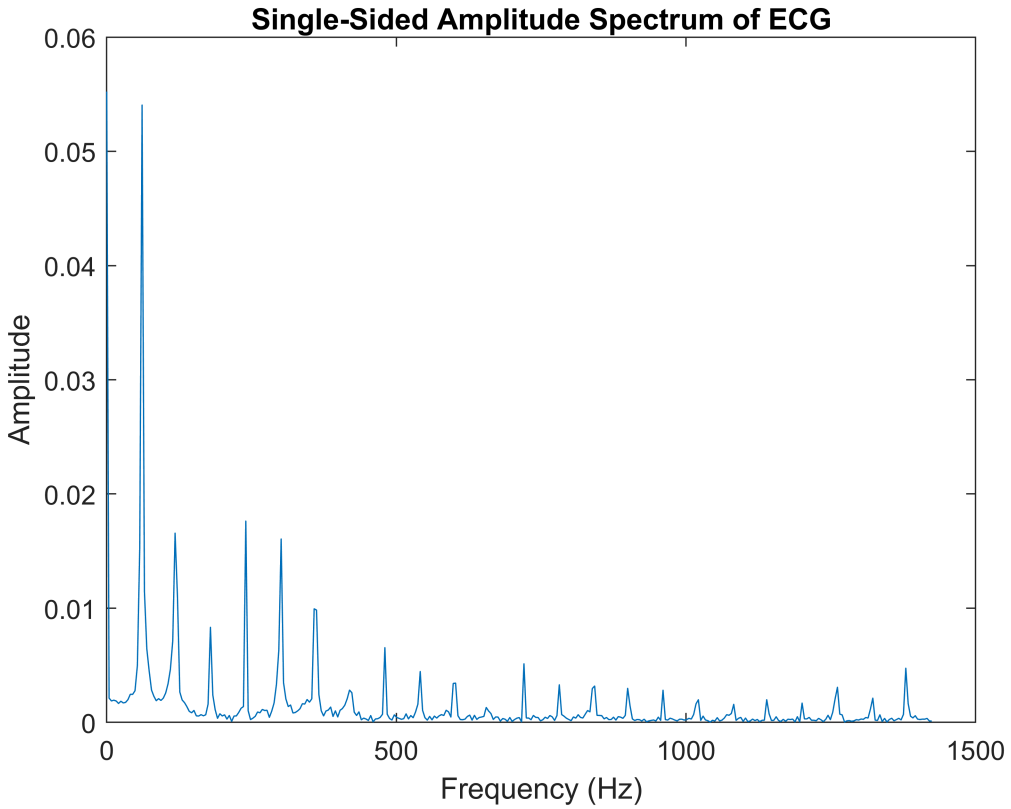



```
phasez(b) %phase response
title('Phase Response - 4.7K Ohm Resistor')
```

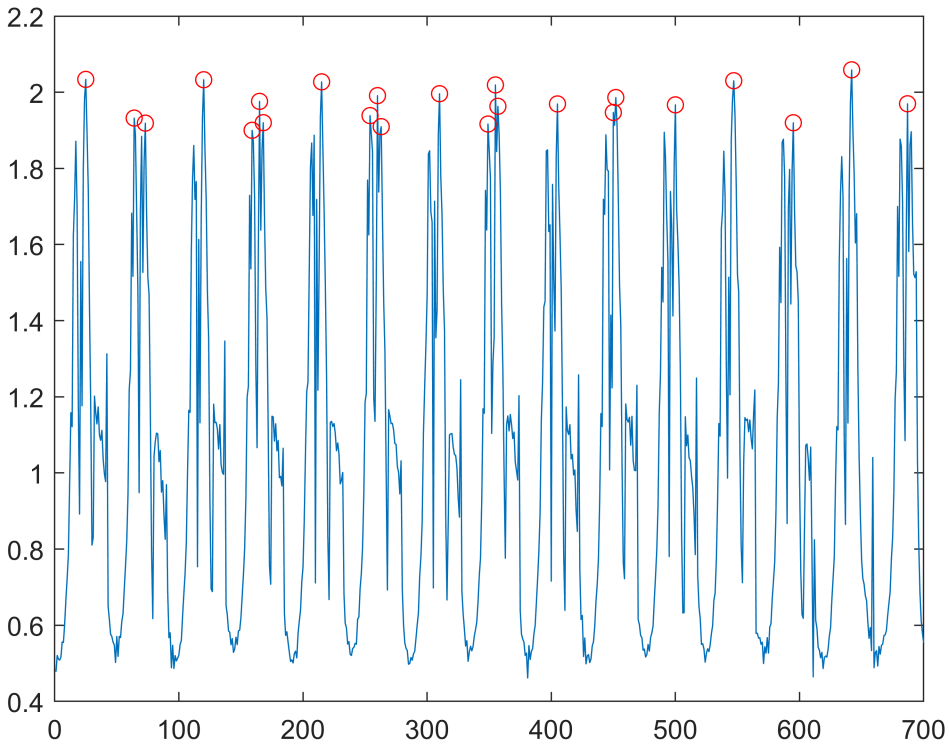





```
Y2 = 700×1 complex
10^2 ×
   6.7869 + 0.0000i
  -0.1037 - 0.0796i
  -0.0195 - 0.1139i
   0.0250 - 0.1168i
   0.0509 - 0.1034i
   0.0708 - 0.0733i
   0.0888 - 0.0716i
   0.0912 - 0.0518i
   0.0969 - 0.0472i
   0.1135 - 0.0459i
      ⋮
```

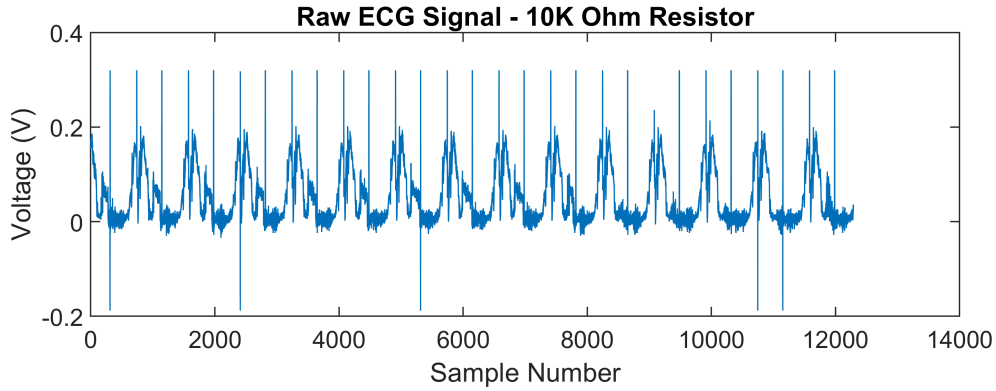


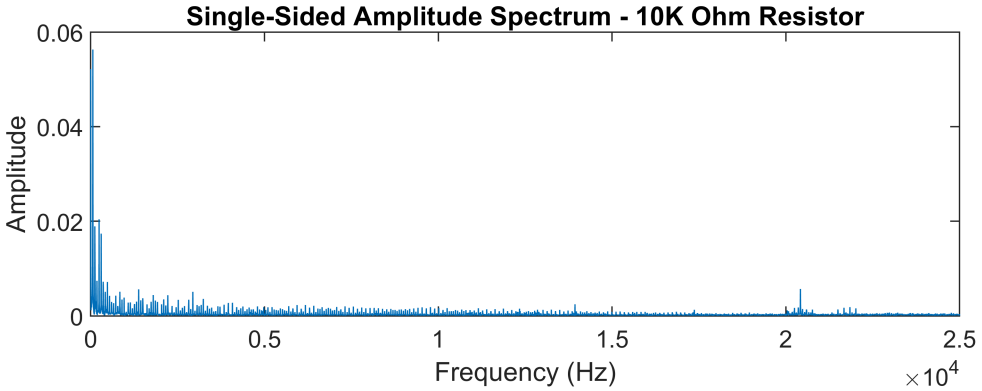

```
B1 = 700×1 complex
   0.4670 + 0.1016i
   0.5171 + 0.0597i
   0.5102 - 0.0269i
   0.5029 - 0.0751i
   0.5020 - 0.1228i
   0.5203 - 0.1967i
   0.4961 - 0.2483i
   0.5163 - 0.3128i
   0.5332 - 0.4021i
   0.5521 - 0.4668i
      ⋮
```



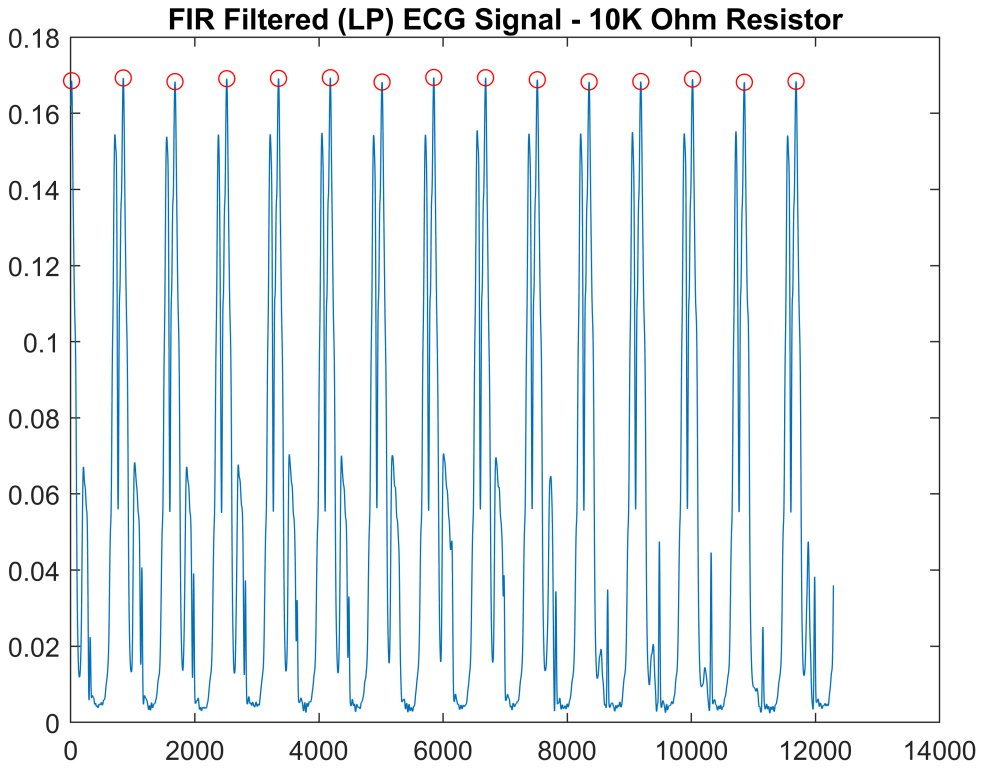

```
%% 10K Ohm Resistor

clear
clc
close all
%Import and plot raw ECG data
data = readmatrix('10k_ohmECG.CSV'); %imports data from Excel into a matrix
A = data(:,2); %extracts just the voltage values (col #2)
figure
subplot(2,1,1)
plot(A)
title('Raw ECG Signal - 10K Ohm Resistor')
xlabel('Sample Number')
ylabel('Voltage (V)')

%Generate frequency magnitude spectrum using FFT
fs = 50000; %sampling frequency (Hz)
L = length(A); %length of signal
y = fft(A);
ds = abs(y/L); %double-sided amplitude spectrum
ss = ds(1:(L/2)+1);
ss(2:end-1) = 2*ss(2:end-1); %single-sided amplitude spectrum
f = (0:L/2)*fs/L; %frequency axis in Hz
subplot(2,1,2)
plot(f,ss)
xlabel('Frequency (Hz)')
```

```
ylabel('Amplitude')
title('Single-Sided Amplitude Spectrum - 10K Ohm Resistor')
```

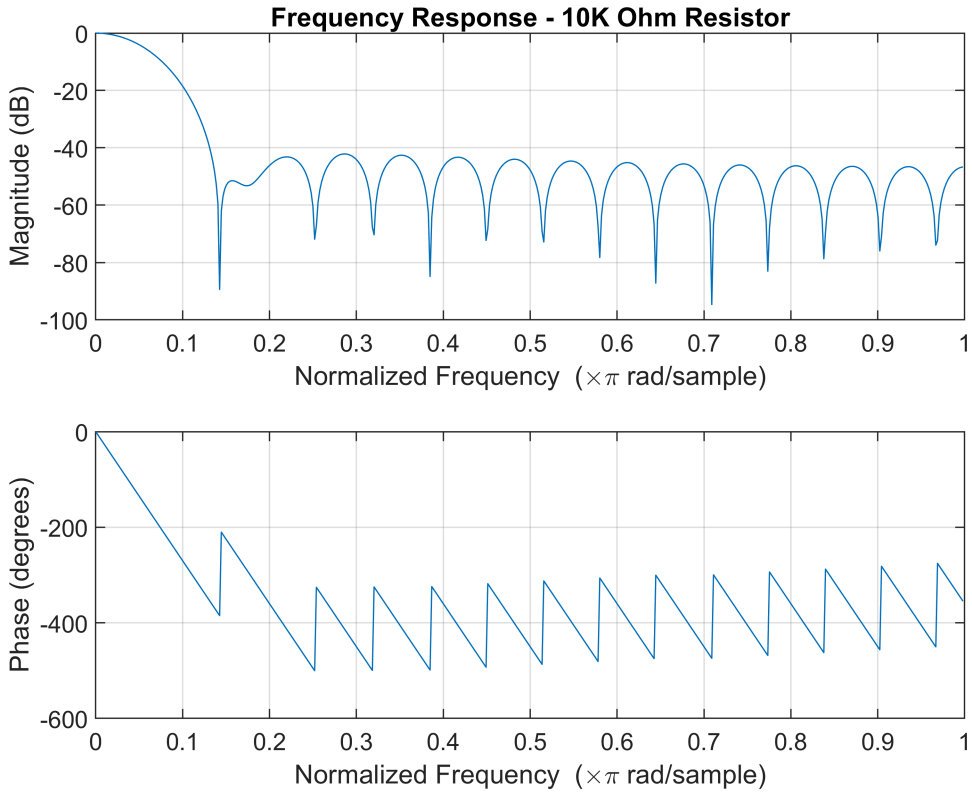




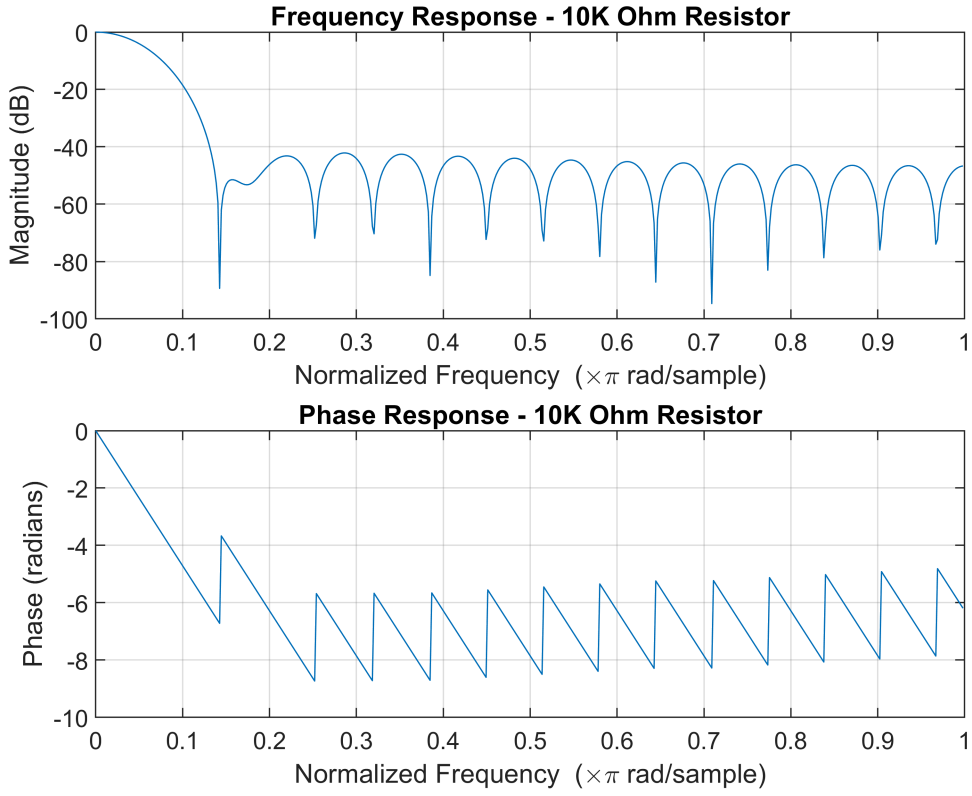

```
%FIR lowpass filter
fn = fs/2; %Nyquist frequency
fc = 310; %cut-off frequency
n = 30; %filter order
b = fir1(n,fc/fn);
z = filtfilt(b,1,A); %zero-phase filtering
figure
plot(z)
title('FIR Filtered (LP) ECG Signal - 10K Ohm Resistor')

%Detect R peaks
[pk,x] = findpeaks(z,'MinPeakHeight',0.16); %finds all R peaks and stores their indices in vect
hold on
plot(x,pk,'ro')
```



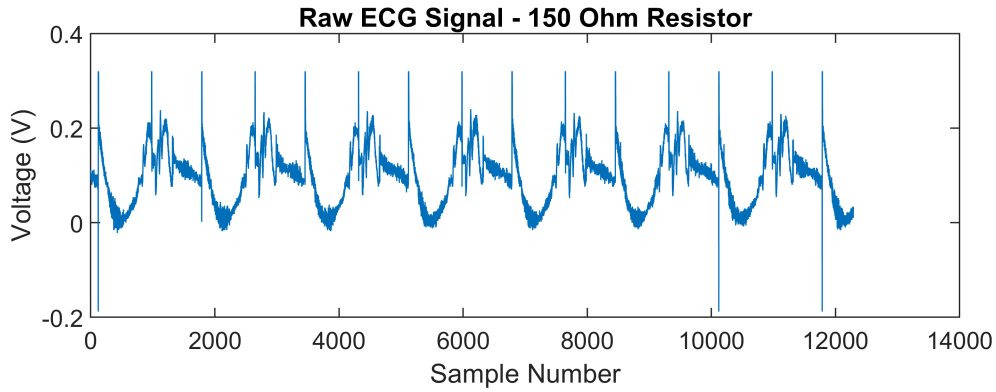

```
%Method 3
trr=x(2)-x(1)
bpm3=1/(trr*10^(-3))*60

%Frequency and phase response of lowpass FIR filter
figure
subplot(2,1,1)
freqz(b) %frequency response
title('Frequency Response - 10K Ohm Resistor')
subplot(2,1,2)
```

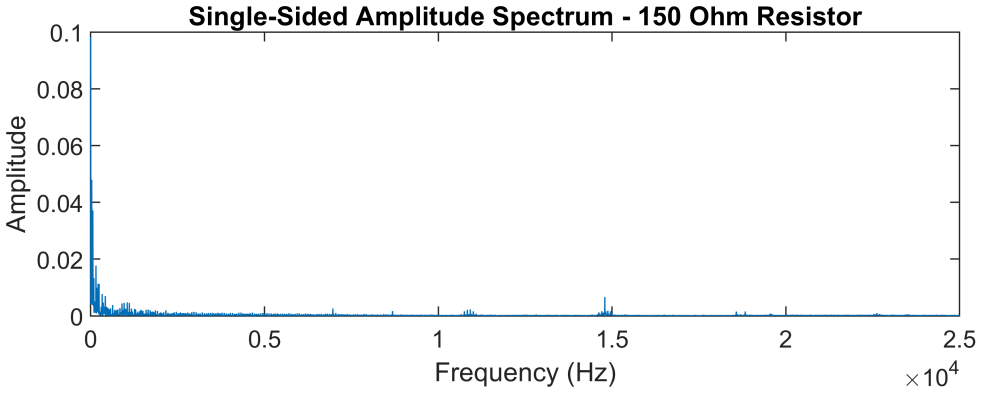



```
phasez(b) %phase response
title('Phase Response - 10K Ohm Resistor')
```

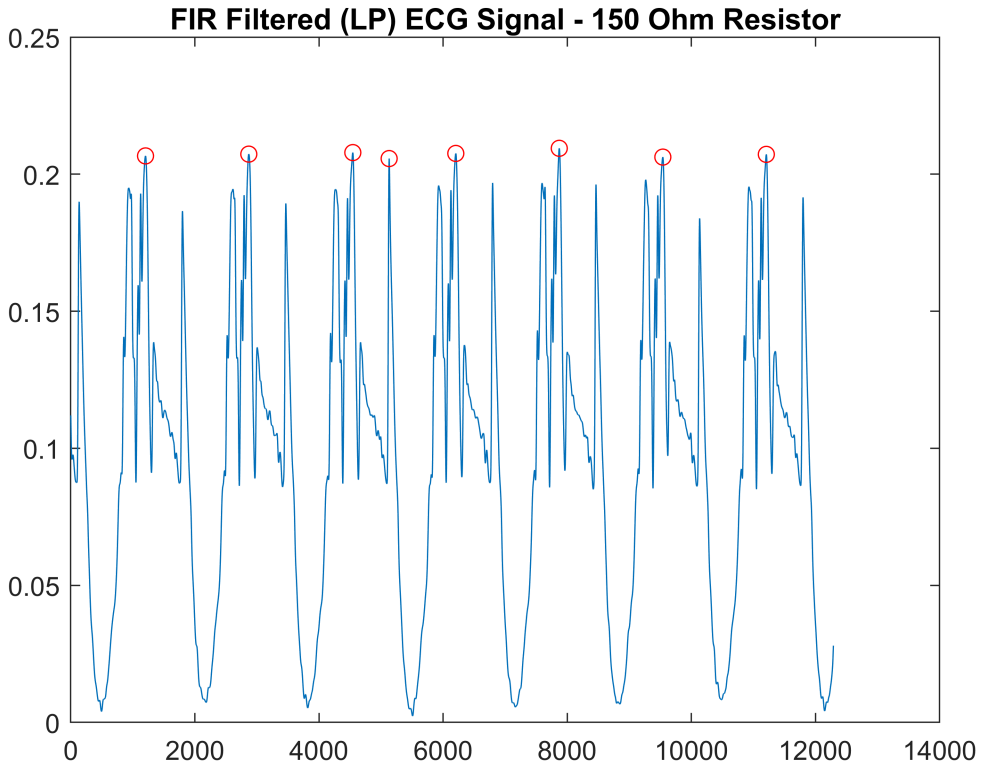


```
%% 150 Ohm Resistor

clear
clc
close all
%Import and plot raw ECG data
data = readmatrix('150_ohmECG.CSV');
A = data(:,2);
figure
subplot(2,1,1)
plot(A)
title('Raw ECG Signal - 150 Ohm Resistor')
xlabel('Sample Number')
ylabel('Voltage (V)')

%Generate frequency magnitude spectrum using FFT
fs = 50000; %sampling frequency (Hz)
L = length(A); %length of signal
y = fft(A);
ds = abs(y/L); %double-sided amplitude spectrum
ss = ds(1:(L/2)+1);
ss(2:end-1) = 2*ss(2:end-1); %single-sided amplitude spectrum
f = (0:L/2)*fs/L; %frequency axis in Hz
subplot(2,1,2)
plot(f,ss)
xlabel('Frequency (Hz)')
ylabel('Amplitude')
title('Single-Sided Amplitude Spectrum - 150 Ohm Resistor')
```






```
%FIR lowpass filter
fn = fs/2; %Nyquist frequency
fc = 250; %cut-off frequency
n = 30; %filter order
b = fir1(n,fc/fn);
z = filtfilt(b,1,A);
figure
plot(z)
title('FIR Filtered (LP) ECG Signal - 150 Ohm Resistor')

%Detect R peaks
[pk,x] = findpeaks(z,'MinPeakHeight',0.2); %finds all R peaks and stores their indices in vecto
hold on
plot(x,pk,'ro')
```



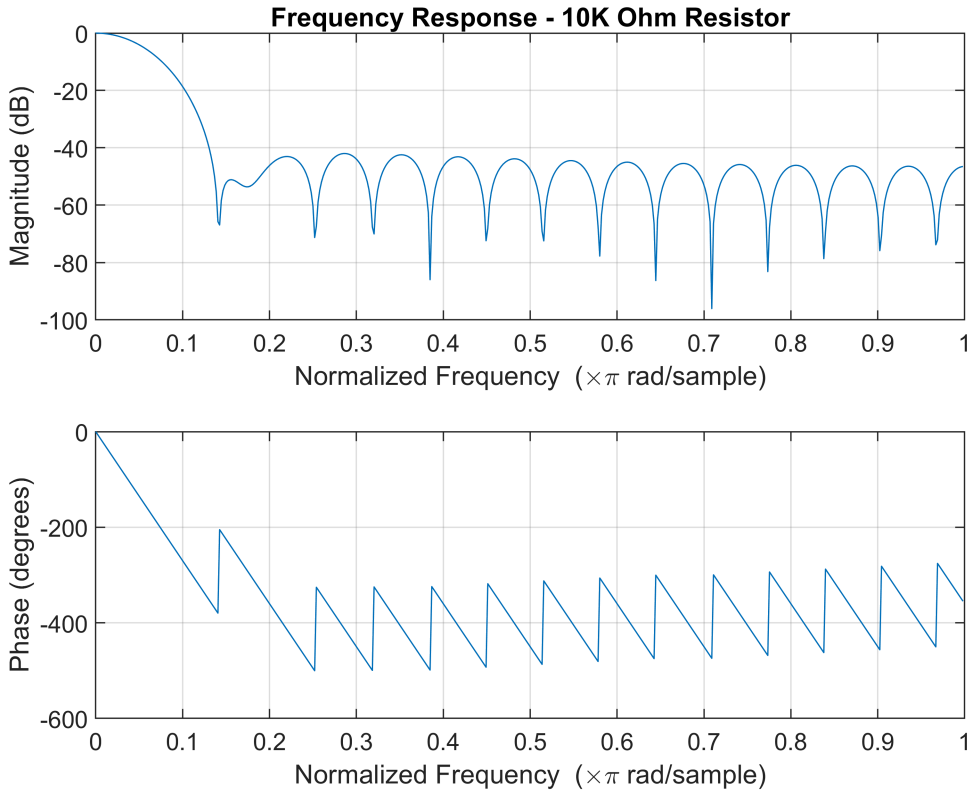

```
%Method 3
trr=x(2)-x(1)
```

```
trr = 1664
```

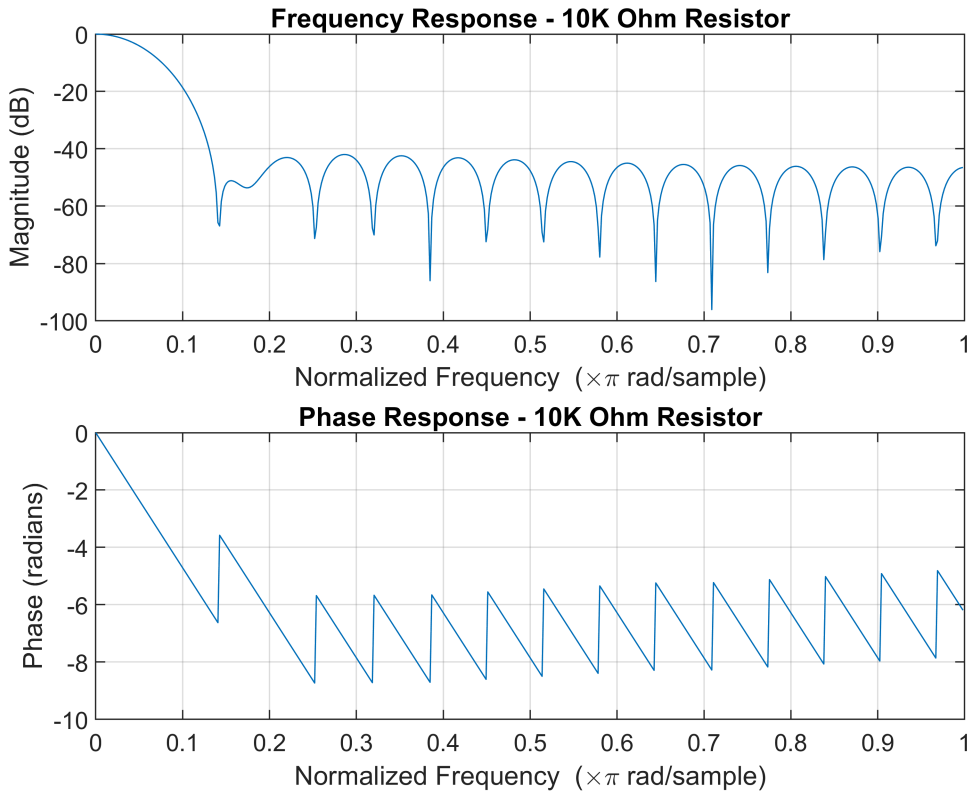
```
bpm3=1/(trr*10^(-3))*60
```

```
bpm3 = 36.0577
```

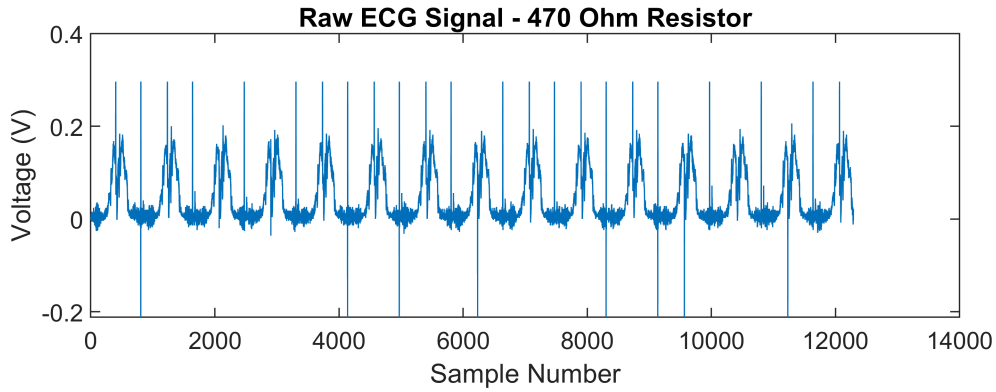
```
%Frequency and phase response of lowpass FIR filter
figure
subplot(2,1,1)
freqz(b) %frequency response
title('Frequency Response - 10K Ohm Resistor')
subplot(2,1,2)
```

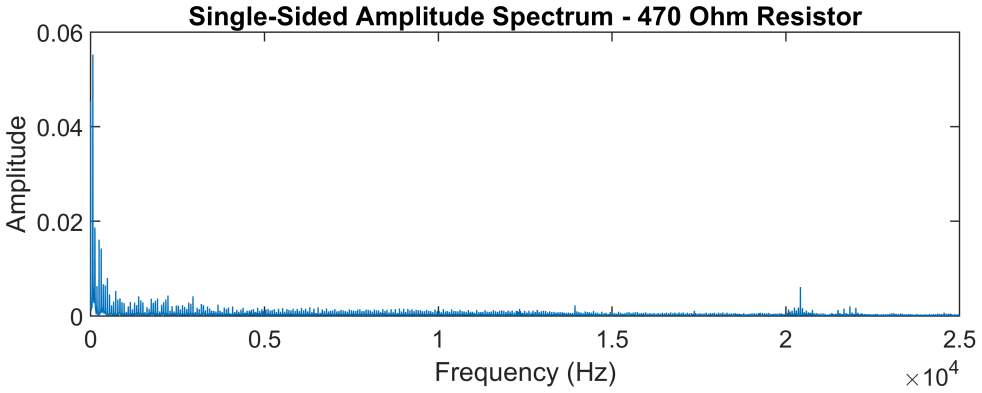



```
phasez(b) %phase response
title('Phase Response - 10K Ohm Resistor')
```

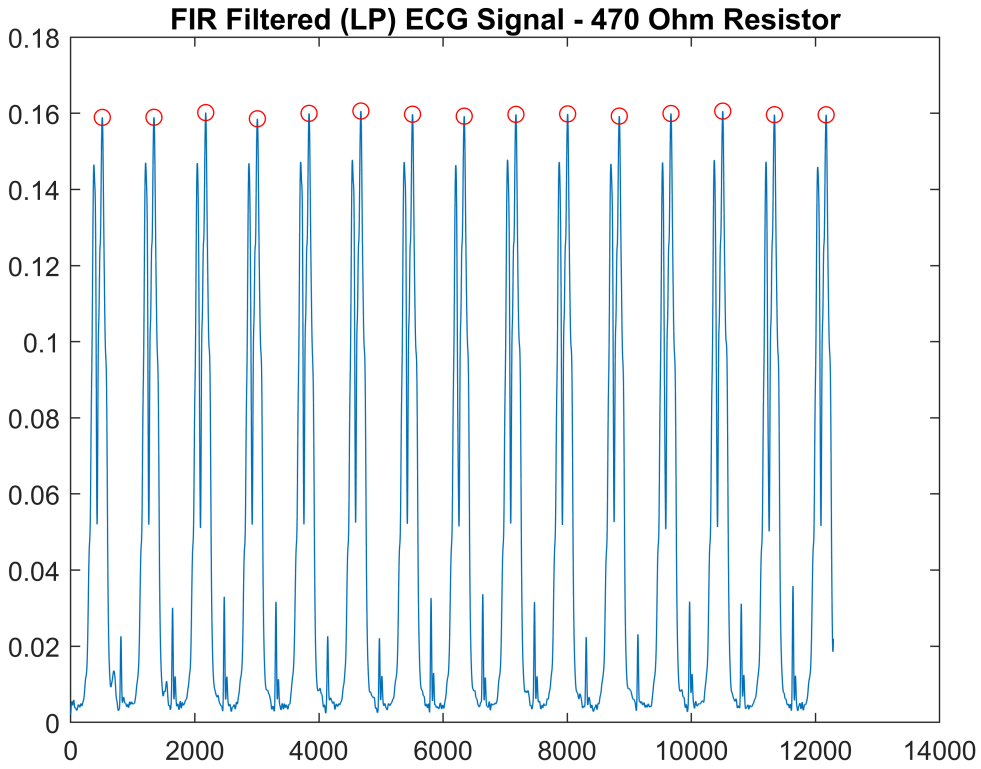


```
%% 470 Ohm Resistor
clear
clc
close all

%Import and plot raw ECG data
data = readmatrix('470_ohmECG.CSV');
A = data(:,2);
figure
subplot(2,1,1)
plot(A)
title('Raw ECG Signal - 470 Ohm Resistor')
xlabel('Sample Number')
ylabel('Voltage (V)')

%Generate frequency magnitude spectrum using FFT
fs = 50000; %sampling frequency (Hz)
L = length(A); %length of signal
y = fft(A);
ds = abs(y/L); %double-sided amplitude spectrum
ss = ds(1:(L/2)+1);
ss(2:end-1) = 2*ss(2:end-1); %single-sided amplitude spectrum
f = (0:L/2)*fs/L; %frequency axis in Hz
subplot(2,1,2)
plot(f,ss)
xlabel('Frequency (Hz)')
ylabel('Amplitude')
title('Single-Sided Amplitude Spectrum - 470 Ohm Resistor')
```






```
%FIR lowpass filter
fn = fs/2; %Nyquist frequency
fc = 250; %cut-off frequency
n = 30; %filter order
b = fir1(n,fc/fn);
z = filtfilt(b,1,A);
figure
plot(z)
title('FIR Filtered (LP) ECG Signal - 470 Ohm Resistor')

%Detect R peaks
[pk,x] = findpeaks(z,'MinPeakHeight',0.15); %finds all R peaks and stores their indices in vect
hold on
plot(x,pk,'ro')
```



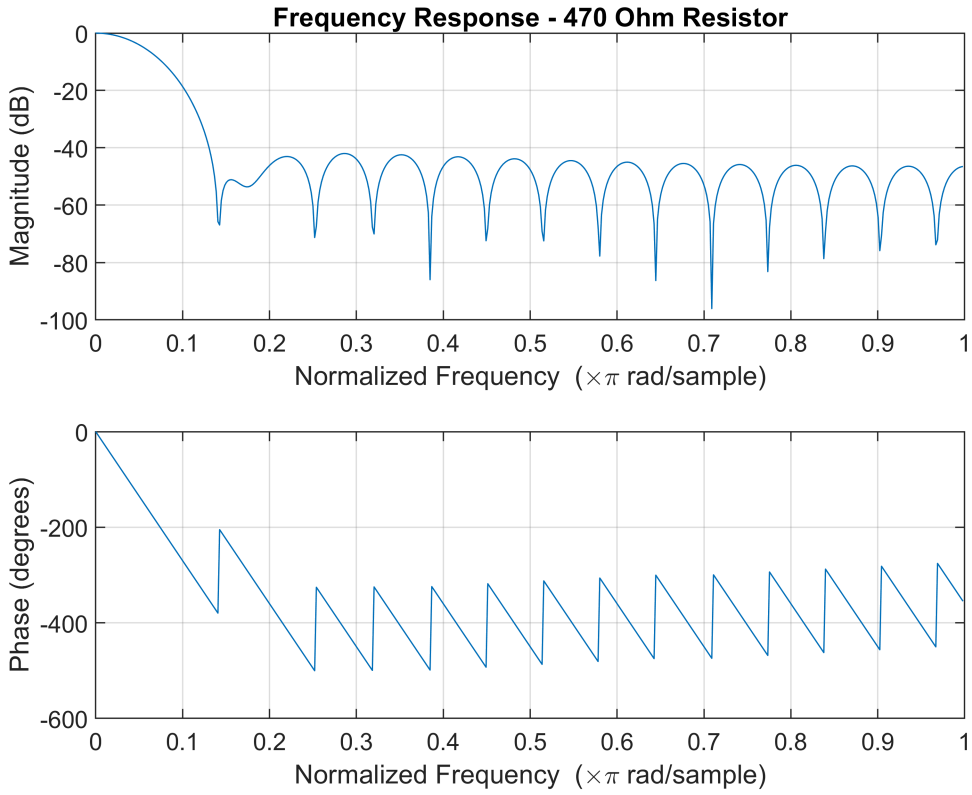

```
%Method 3
trr=x(2)-x(1)
```

```
trr = 832
```

```
bpm3=1/(trr*10^(-3))*60
```

```
bpm3 = 72.1154
```

```
%Frequency and phase response of lowpass FIR filter
figure
subplot(2,1,1)
freqz(b) %frequency response
title('Frequency Response - 470 Ohm Resistor')
subplot(2,1,2)
```




```
phasez(b) %phase response
title('Phase Response - 470 Ohm Resistor')
```