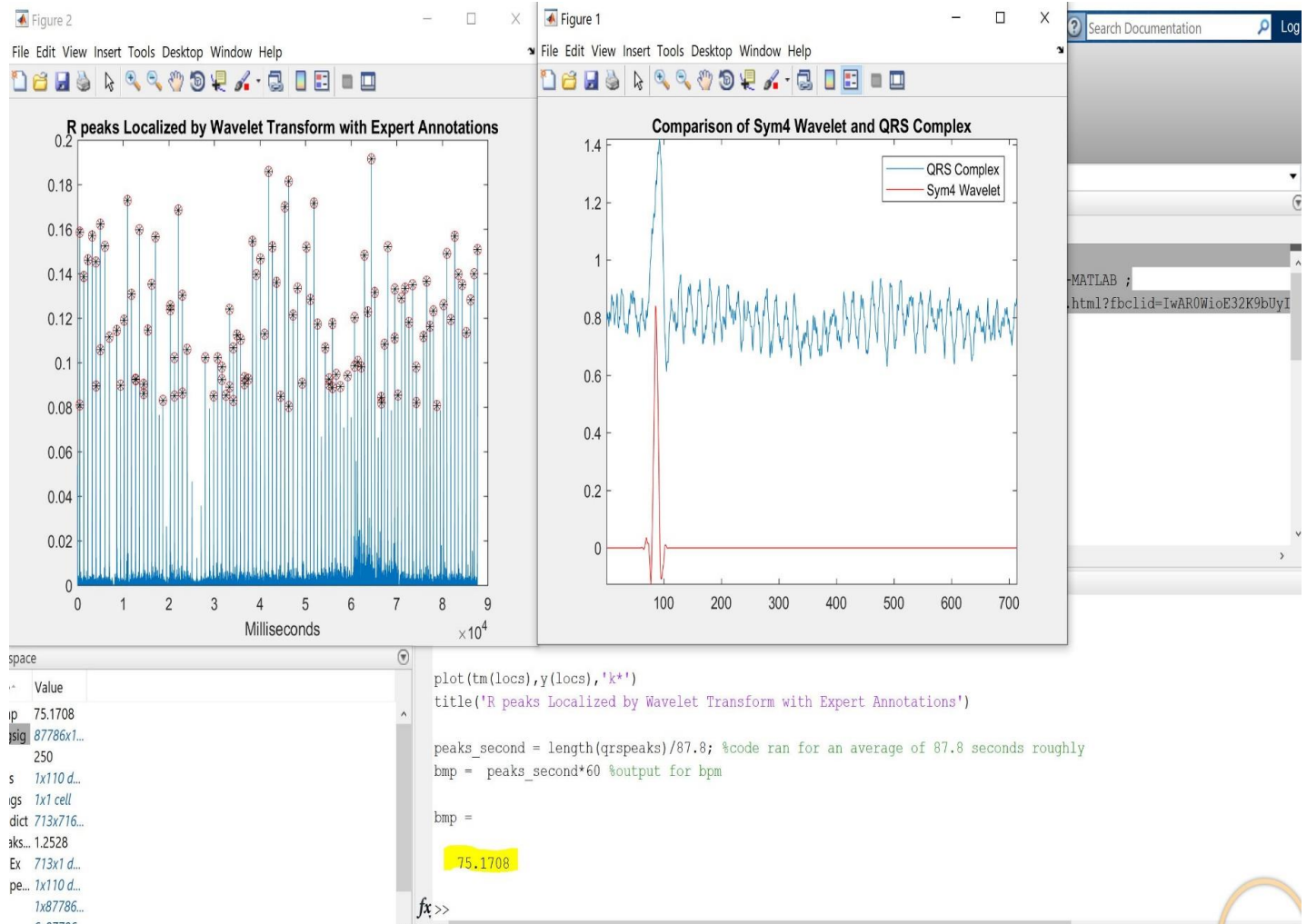**Question 1:**

*Refer to *page 2 for Matlab graph and page 5 for code typed*. The resulting BPM measured from excel sheet is **BPM = 75.708.** A wavelet transform was referenced from Matlab was utilized to identify the number of R peaks over a period of 87.8 seconds. Basic understanding of the code, implementing a row of element and typing variables for the last part of the code segment to get the BPM was required to obtain the actual output.

Error = *Abs(Measured BPM - Recorded BPM from Matlab (Error)) / Recorded BPM from Matlab (Error)*

- Measured BPM was taken in the lab previously = 78
- Error =(Abs(78-75) / 75)* 100 = **4% error**

Possible Causes of Error:

1. External Environment Interferences: Nearby Electronics, noisy environment)
2. Physical Artefacts: Patient might have irregular heart abnormalities, patient might have triggered a higher bpm when excited from external stimulus (i.e shock & stress)
3. The patient taking the measurement may have exercise or did more rigorous activiy before the experiment, this stimulates heart rate
4. Hardware issue of probes onto the contact of skin, the wire hooked up to the monitor might emit some DC offset current, old equipment which slows down overall accuracy of ECG meeting

R peaks Localized by Wavelet Transform with Expert Annotations

Milliseconds ×10⁴

Comparison of Sym4 Wavelet and QRS Complex

- QRS Complex
- Sym4 Wavelet

```
plot(tm(locs),y(locs),'k*')
title('R peaks Localized by Wavelet Transform with Expert Annotations')

peaks_second = length(qrspeaks)/87.8; %code ran for an average of 87.8 seconds roughly
bmp =  peaks_second*60 %output for bpm


bmp =

    75.1708

fx >>
```

Question 2:
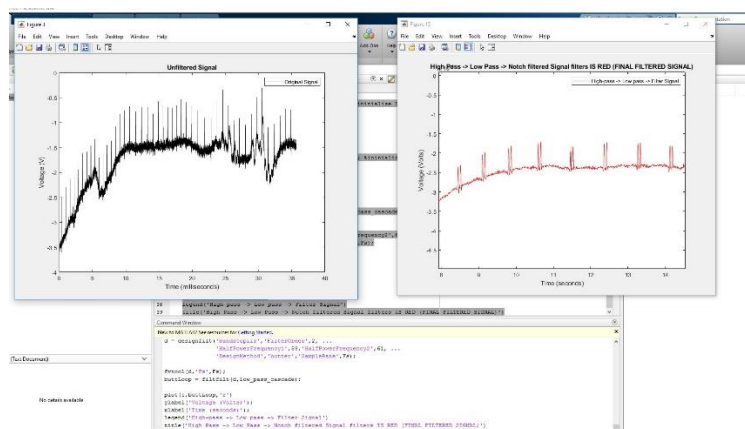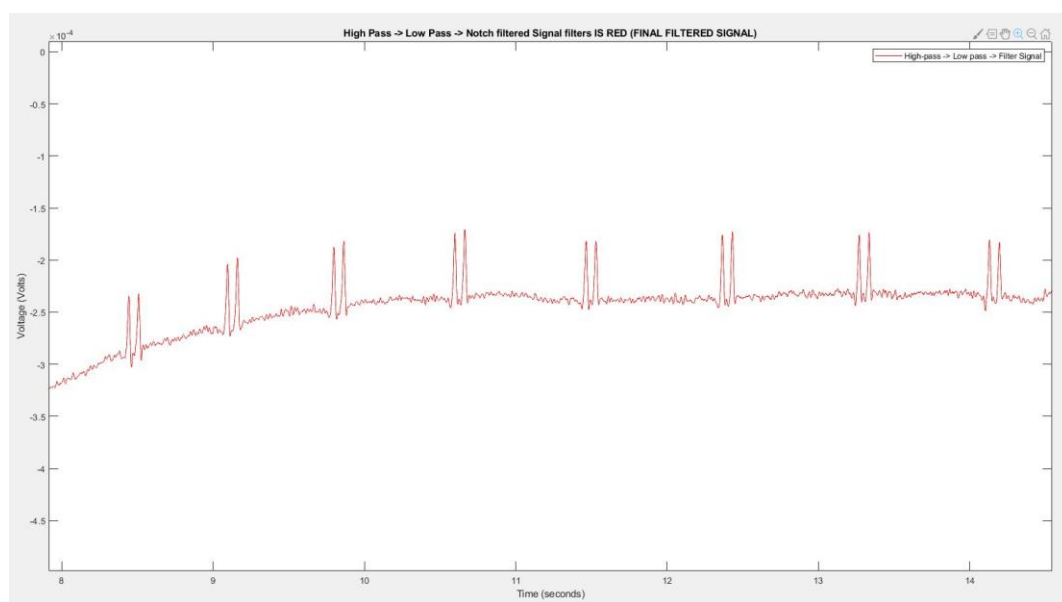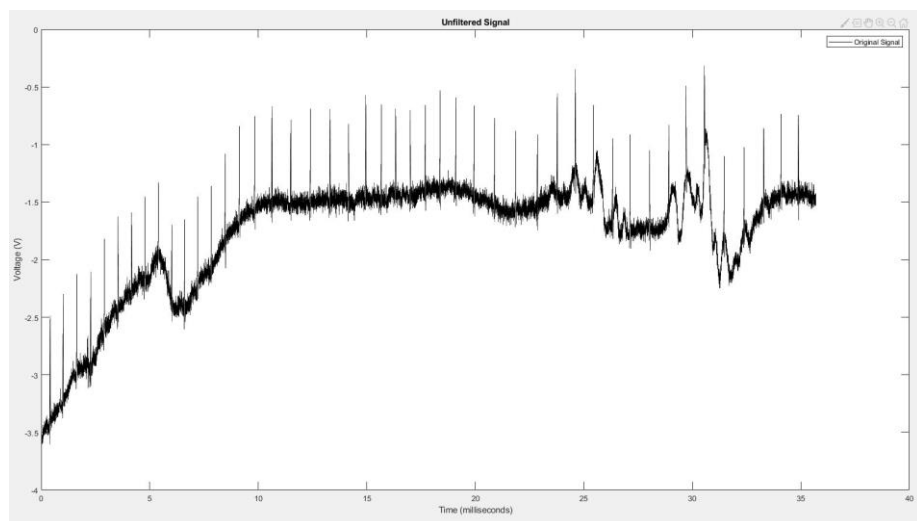
*Refer to *page 4 for Matlab graph and page 6 for code typed*. The `functions lowpass(), highpass(), d = designfilt(), fvtool(), filtfilt()` was used to initialized the highpass, lowpass and notch filter cascade application. The left side of page 4 shows the unfiltered noise graph and the right side shows the filtered signal after the lowpass, highpass and notch filtered were applied.

Advantage:

1. Eliminating high frequency disregard artifacts (i.e. D.C. offset of cable, muscle artefacts, electrical noise from the machines and sounds from external environment, sneezing, patient movement)
2. Eliminating low frequency disregards data that might be caused by improper application/ poor contact of electrodes on the skin or poor contact
3. Will not interfere with cutting out the ST measurement interval; rarely cuts out the period of two consecutives cycles – accentuates the display of the actual ECG.
4. Good when filtering signals that has a linear phase; avoids phase distortion that can alter the temporal relationships in a cardiac cycle

Disadvantage:

1. Real life application. Might miss out on detecting muscle abnormalities if the patient/person under test has actual some minor skeletomuscular disease.
2. If not sample at the right sampling rate, the EMG output signal can either become aliased or turn into an absolute DC signal
3. It might dampen or slow down the output signal at steep slopes when implementing the low pass filter
4. It might output irregular peak values or lose shape of an original EMG signal (oversampling).

Unfiltered Signal

High Pass -> Low Pass -> Notch filtered Signal filters IS RED (FINAL FILTERED SIGNAL)

Matlab Code Question 1:

```matlab
% Citation : code was typed based on the help of referencing wavelet transform -MATLAB
;
% Source: https://www.mathworks.com/help/wavelet/ug/r-wave-detection-in-the-
ecg.html?fbclid=IwAR0WioE32K9bUyI_rvLe3V62Ib6_g3682Fk51vv70fka9VLuOtValGIV3j0

load mit200 % contains the column vector with the signal of interest channel 1
tm = 1:numel(ecgsig);  % load number of elements generated
qrsEx = ecgsig(34088:34800);
[mpdict,~,~,longs] = wmpdictionary(numel(qrsEx),'lstcpt',{{'sym4',3}});
figure
plot(qrsEx)
hold on
plot(2*circshift(mpdict(:,11),[-2 0]),'r')
axis tight
legend('QRS Complex','Sym4 Wavelet')
title('Comparison of Sym4 Wavelet and QRS Complex')

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
wt = modwt(ecgsig,5);
wtrec = zeros(size(wt));
wtrec(4:5,:) = wt(4:5,:);
y = imodwt(wtrec,'sym4');

y = abs(y).^2;
[qrspeaks,locs] = findpeaks(y,tm,'MinPeakHeight',0.08,... %% how much of a spike
before you read as a peak
    'MinPeakDistance',0.08);
figure
plot(tm,y)
hold on
plot(locs,qrspeaks,'ro')
xlabel('Milliseconds')
title('R Peaks Localized by Wavelet Transform with Automatic Annotations')

plot(tm(locs),y(locs),'k*')
title('R peaks Localized by Wavelet Transform with Expert Annotations')

peaks_second = length(qrspeaks)/87.8; %code ran for an average of 87.8 seconds roughly
bmp =  peaks_second*60 %output for bpm
```

Matlab Code Question 2:

```matlab
%a vector variable called emgsig was imported from excel for this matlab
Fs = 1000;
t = (0:length(emgsig)-1)/Fs;
%t = 0:1/Fs:1;

plot(t,emgsig, 'k');
ylabel('Voltage (V)');
xlabel('Time (milliseconds)');
legend('Original Signal');
title('Unfiltered Signal');

high_pass_cascade = highpass(emgsig(:,1),400,Fs); %initialize low_pass_after notch
(Cascade)
%plot(t,high_pass_cascade, 'b');
%ylabel('Voltage (V)');
%xlabel('Time (milliseconds)');
%legend('High Pass filtered Signal');
%title('High Pass filtered Signal');

low_pass_cascade = lowpass(high_pass_cascade,20,Fs); %initialize high_pass_after low +
notch filter (Cascade)
%plot(t,low_pass_cascade, 'm');
%ylabel('Voltage (V)');
%xlabel('Time (milliseconds)');
%legend('High Pass -> Low Pass filtered Signal');
%title('High Pass -> Low Pass filtered Signal');

%plot(t,ecgsig, 'b',t,high_pass_cascade, 'r',t,low_pass_cascade, 'g')

d = designfilt('bandstopiir','FilterOrder',2, ...
               'HalfPowerFrequency1',59,'HalfPowerFrequency2',61, ...
               'DesignMethod','butter','SampleRate',Fs);

fvtool(d,'Fs',Fs);
buttLoop = filtfilt(d,low_pass_cascade);

plot(t,buttLoop,'r')
ylabel('Voltage (Volts)');
xlabel('Time (seconds)');
legend('High-pass -> Low pass -> Filter Signal')
title('High Pass -> Low Pass -> Notch filtered Signal filters IS RED (FINAL FILTERED
SIGNAL)')
```