3.1

Plots of time and frequency domains are shown below.

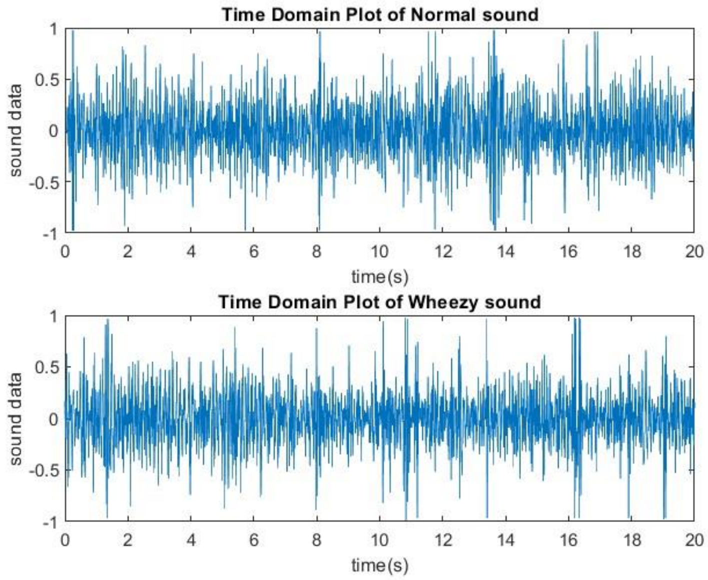

Figure 1 The time domain plots of normal sounds representing raw data across 20 seconds

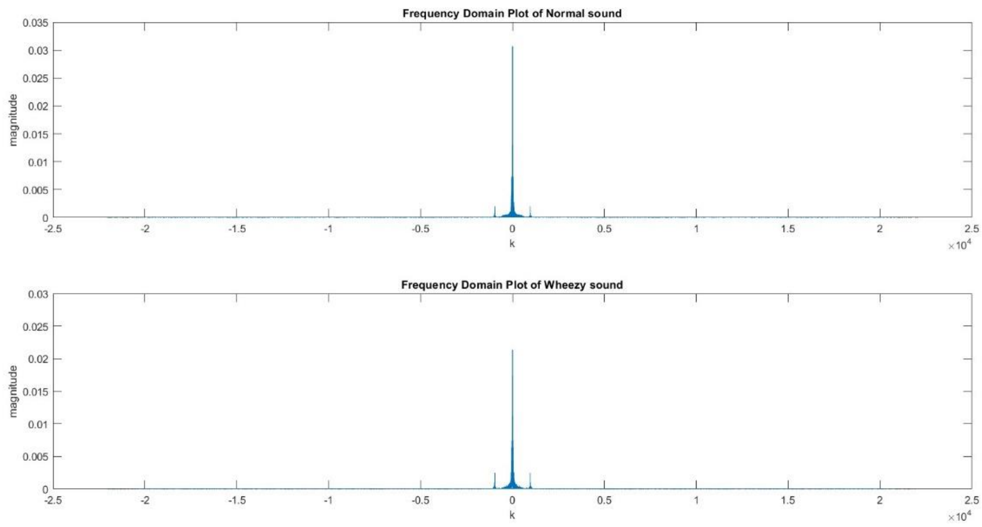

Figure 2 The frequency domain plot of sounds representing magnitude of Fourier coefficients across k(multiples)

The presences of wheeze sound are shown in table 1. The number of samples was derived by multiplying sampling frequency with time length in second.

Time Intervals (s)	Samples
1-7	264600
9-11	88200
14-18	176400

Table 1 Table representing 3 intervals where wheeze sound is present with corresponded number of sample

It is true that frequency domain plots of normal and wheezy sounds are different where the magnitude of low frequency component is lower in wheezy sound. However, the low frequency components are from noise. Therefore, it is not possible to differentiate normal breathing and wheezing using only frequency domain.

3.2

Down-sampling with factor 5 was done by an IIR filtering method. The anti-aliasing was utilized before down sampling in order to restrict the bandwidth of the signal

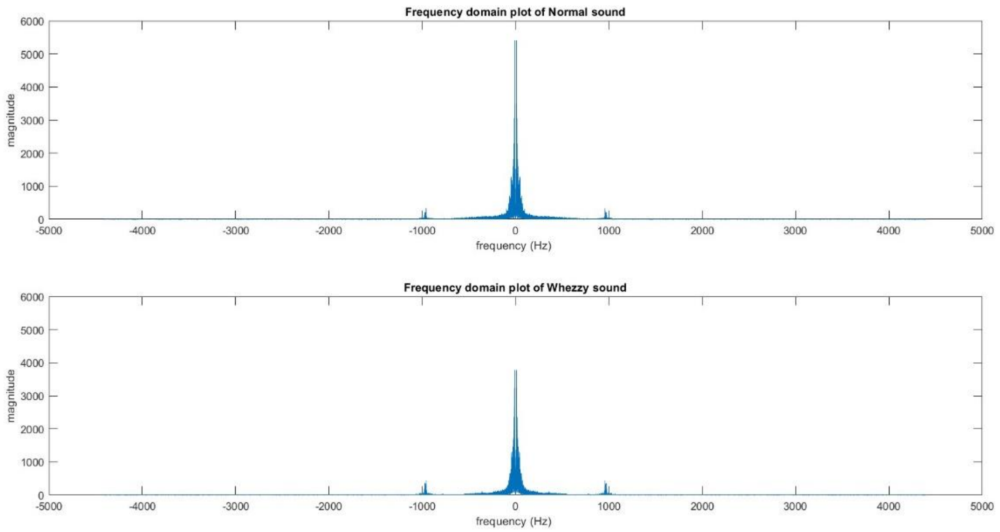

Figure 3 Frequency domain plot of Normal(upper) and Wheezing(lower) of down sampled data

Using factor of 5 preserves the breath sound contents since sampling rate after down sampling is larger than Nyquist rate which is the minimum sampling rate required to recover the signal. If we plot frequency (Hz) domain of raw signal, there is all insignificant signal at frequency more than 1500Hz since the magnitude is almost 0. Therefore, 1500Hz can be used to calculate Nyquist rate which is 3000Hz. As a result of down sampling with factor of 5, new sampling rate 8820 is higher than Nyquist rate, therefore, it is considered as oversampling and the signal is recovered.

The presences of wheeze sound are shown in table 1. The number of samples was derived by multiplying sampling frequency with time length in second.

Time Intervals (s)	Samples
1-7	52920
9-11	17640
17-19	17640

Table 2 Table representing 3 intervals where wheeze sound is present with corresponded number of samples after down sampling

3.3

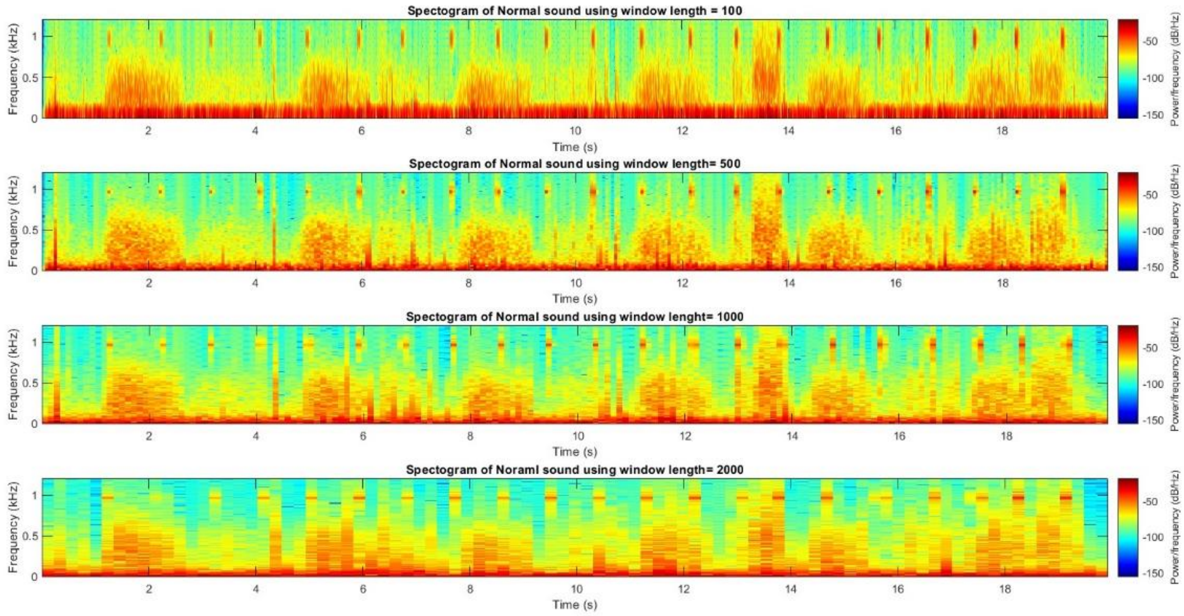

Figure 4 Spectogram of Normal sound after down sampling in 4 different window size

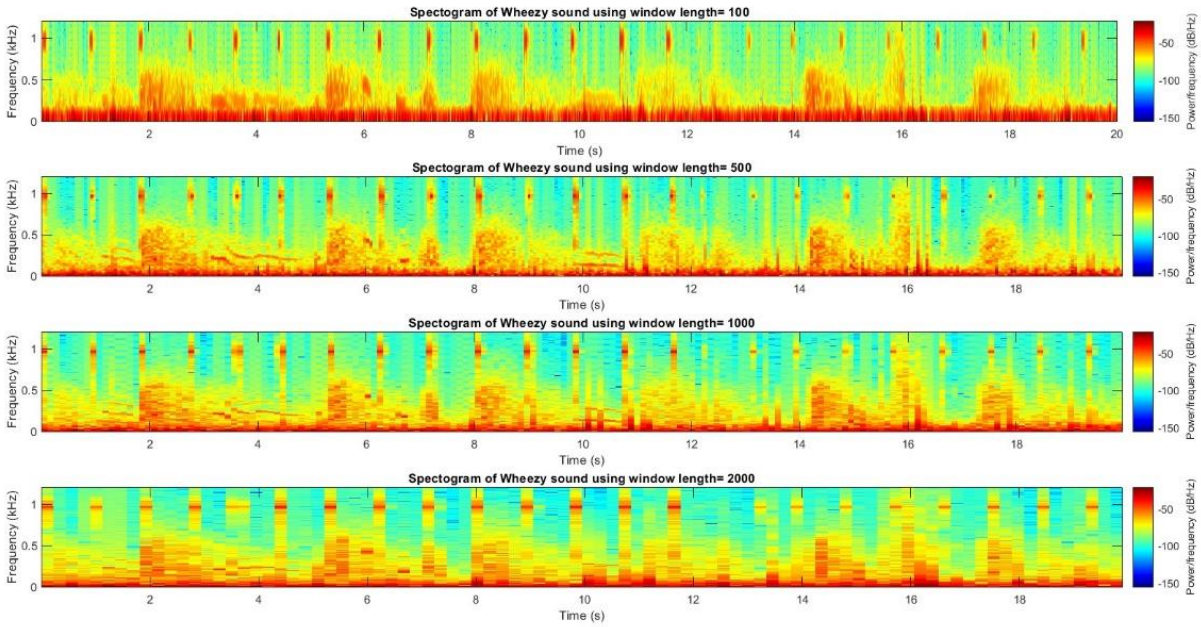

Figure 5 Spectogram of Wheeze sound after down sampling in 4 different window size

The resolution of the spectogram changes accordingly to window lengths. As can be seen from figure 5, smaller window length gives higher resolution in time domain, but lower resolution in frequency domain. Since window length is the number of sample taken to be plotted in 1 window of the spectogram, having less sample per 1 window means that the spectogram would have many more windows until it reaches time range of the signal which is 20 seconds for this signal. As a results, the spectogram has high time resolution due to the number of window. For the frequency resolution, the window length expresses the number of frequency bands. As the more frquency band presented in the spectogram, the more resolution in frequency the spectogram has, high window length leads to high frequency resolution.

To determine the optimal spectogram, both frequency and time resolution are considered since the purpose is to distinguish beep noise which can be differentiate by frequency band and specify time intervals of wheeze sound. It was found that the optimal window length is 500 samples.

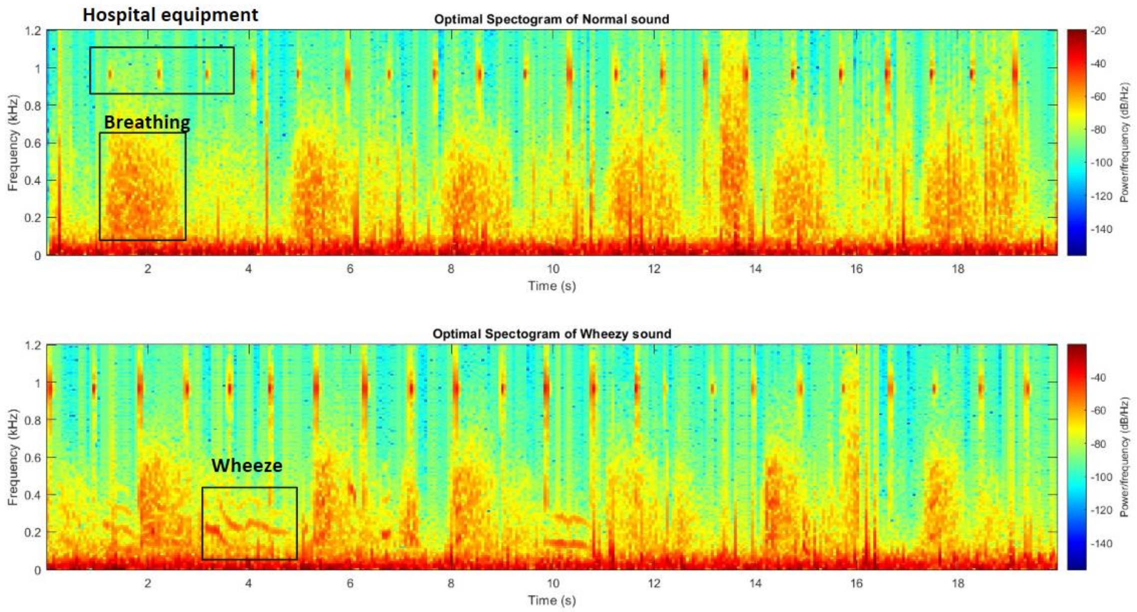

Figure 6 Optimal Spectogram with annotated location of sound from hospital equipment normal breathing and wheezing.

Since the frequency band of beep noise from the hospital equipment is different from both normal breathing and wheeze sound, beep noise can be removed. Not only the beep noise that can be removed, other sources of noise such as baseline happening at low frequency can be removed as well since the frequency of other noises are lower than both breath sound and wheezes.

3.4

Plot of time domain and spectogram are shown below

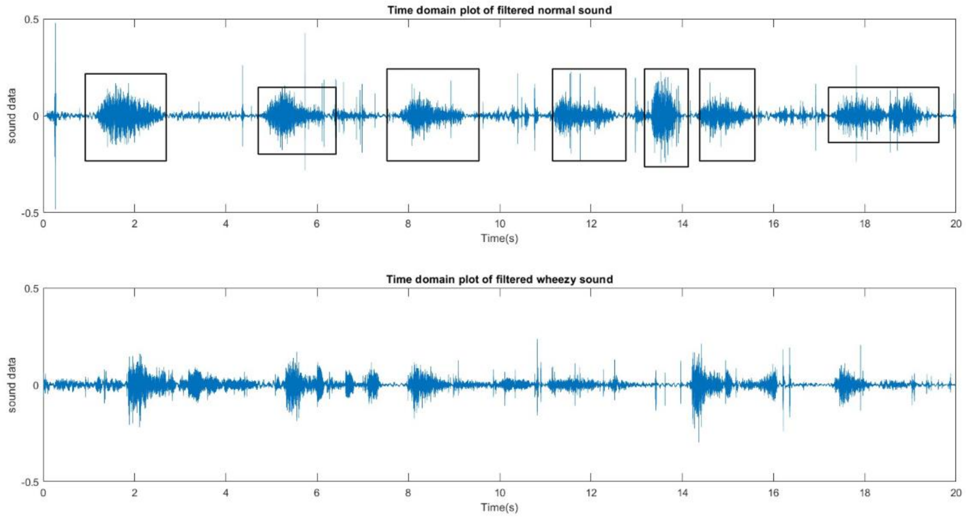

Figure 6 Time domain plot signals after filtering out the beep noise and other sources of noise with annotated breath phase across 20s

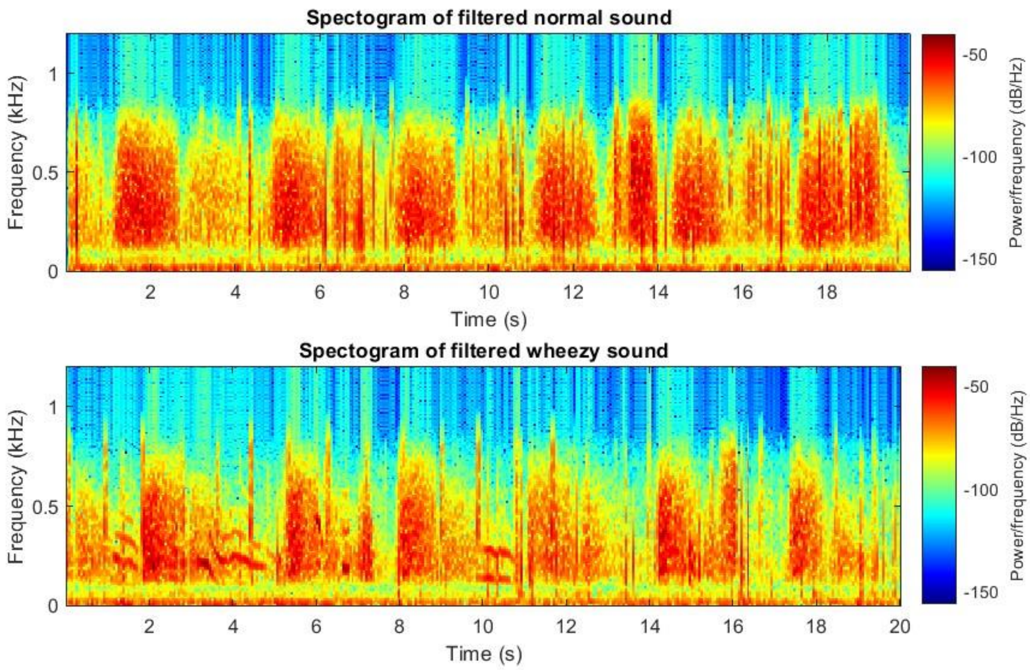

Figure 7 Spectogram of signal after filtering out the beep noise and other sources of noise.

As can be seen from the figure 6 , breath phases are located as annotated in black square.