SNS Coding Assignment

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Introduction

Our mission was to develop a code/script to analyse signals by comparing input and output signals after filtering. By employing FIR filters (low-pass, high-pass, and band-pass), our aim was to determine the type of filtering applied to the input signal. This report documents our approach, implementation, and findings from the analysis. In this report, we have shown the graphs and results for 5 different filter parameters, to show that all three filters can be matched to output signal, given the appropriate filter parameters used.

Concise definitions for each type of filter:

1. Low-pass Filter (LPF):
   - A low-pass filter allows signals below a certain cutoff frequency to pass while attenuating higher frequencies. It's commonly used to remove high-frequency noise or extract low-frequency components from a signal.
2. Band-pass Filter (BPF):
   - A band-pass filter selectively allows signals within a specified frequency range, known as the passband, to pass through while attenuating frequencies outside this range. It's utilized in telecommunications to isolate specific frequency bands for transmission or reception.
3. High-pass Filter (HPF):
   - A high-pass filter permits signals above a specified cutoff frequency to pass while suppressing lower frequencies. It's often used in applications like edge detection in image processing to enhance high-frequency details.

Methodology

Our methodology involved the following steps:

- **Reading Input and Output Signals:** We began by loading the input signal, x(t), and the output signal, y(t), from text files.
- **Filter Specifications:** Defining parameters such as sampling frequency (fs) and cutoff frequencies (fc_lp, fc_hp, fc_bp1, fc_bp2), we specified the characteristics of the FIR filters.
- **Designing FIR Filters:** Using MATLAB's fir1 function, we designed FIR filters based on the specified parameters.

- **Convolution with Input Signal:** We convolved the designed filters with the input signal to obtain filtered outputs, y_lp(t), y_hp(t), and y_bp(t).
- **Comparison using Correlation:** Calculating correlation coefficients between each filtered output and the output signal, we assessed the similarity between them.
- **Identifying the Best Match:** Comparing the correlation coefficients, we determined which filtered output best matched the output signal, indicating the type of filtering applied.
- **Displaying Results:** We visualized the input signal, output signal, filtered outputs, and correlation graphs for better interpretation.

Variables Overview

- **x**: Input signal loaded from the text file.
- **y**: Output signal loaded from the text file.
- **fs**: Sampling frequency.
- **fc_lp, fc_hp, fc_bp1, fc_bp2**: Cutoff frequencies for low pass, high pass, and band pass filters respectively.
- **hlp, hhp, hbp**: Predefined filter coefficients for low pass, high pass, and band pass filters respectively.
- **y_lp, y_hp, y_bp**: Filtered outputs obtained by convolving input signal with corresponding filters.
- **corr_lp, corr_hp, corr_bp**: Correlation coefficients between each filtered output and the output signal.
- **best_match**: Variable storing the identified best matching filter type.

Results & Analysis

The nos. in the brackets are: [fs, fc_lp, fc_hp, fc_bp1, fc_bp2]

Here, fs- sampling frequency, fc_lp-> cutoff for low pass, fc_hp-> cutoff for high pass, fc_bp1-> lower cutoff for band pass, fc_bp2 –>higher cutoff for band pass.

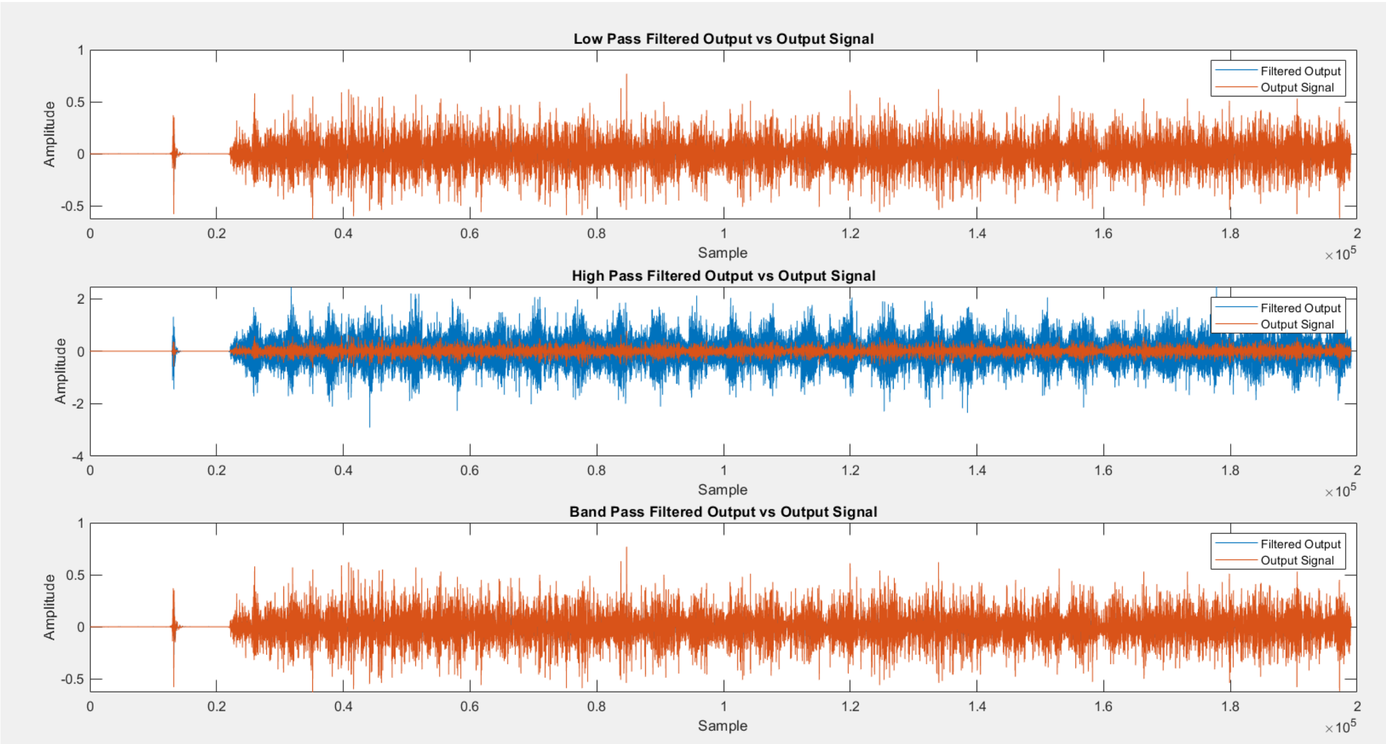
After doing correlation, I have provided the analysis of individual graphs. We varied the parameters significantly to highlight how

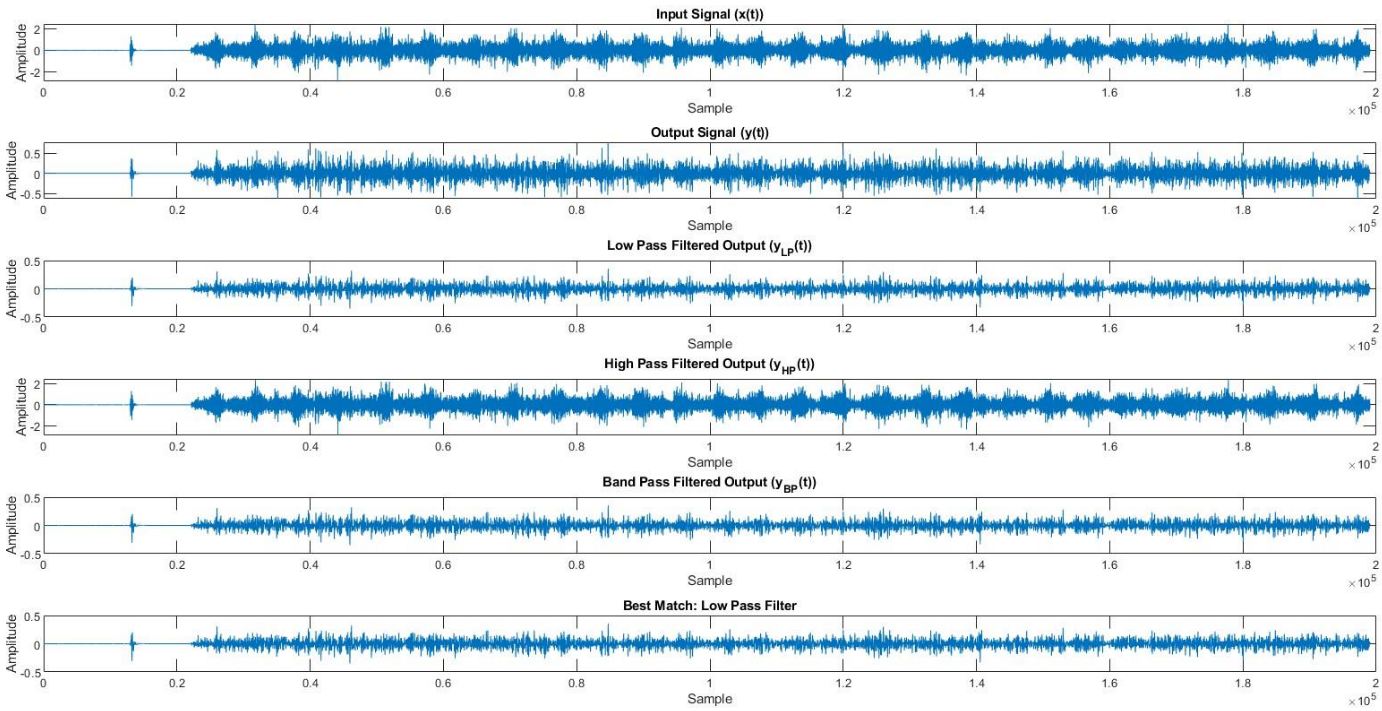
1. **Low-Pass Filter Analysis 1**([44100, 0.1, 0.1, 0.05, 0.15])

   ### Results

   - Correlation coefficients:
     - Low Pass Filter: 35.5477%
     - High Pass Filter: -10.2035%
     - Band Pass Filter: 35.5477%
   - Analysis:
     - The correlation coefficient for the low-pass filter is significantly higher compared to the high-pass and almost similar to band-pass filters, indicating a

strong alignment between the filtered output and the desired output signal. This suggests that the chosen parameters effectively attenuated high-frequency components, resulting in a close match to the output signal.

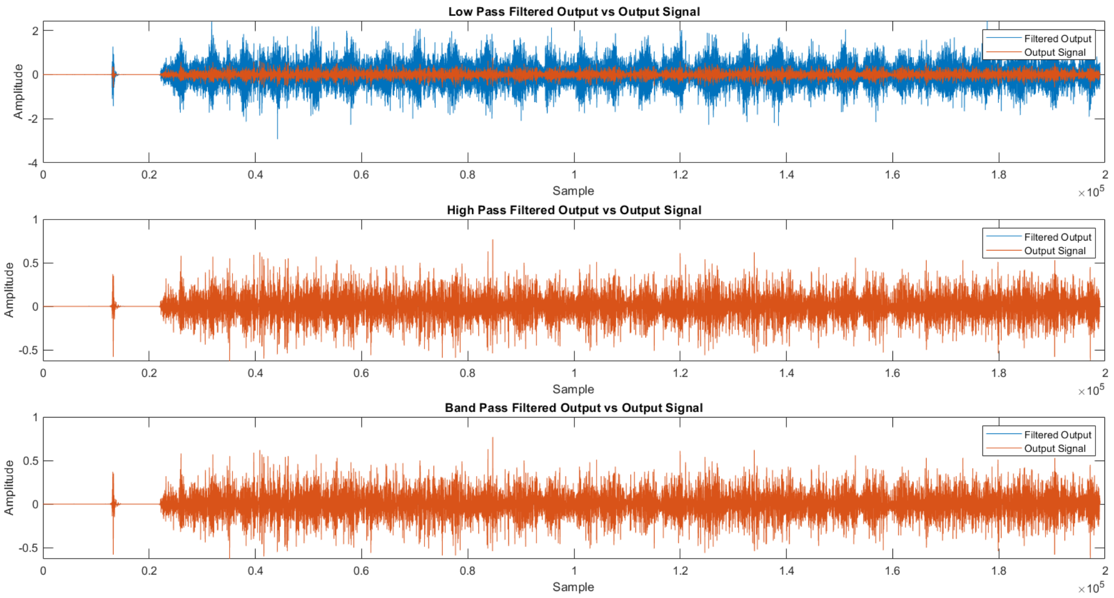


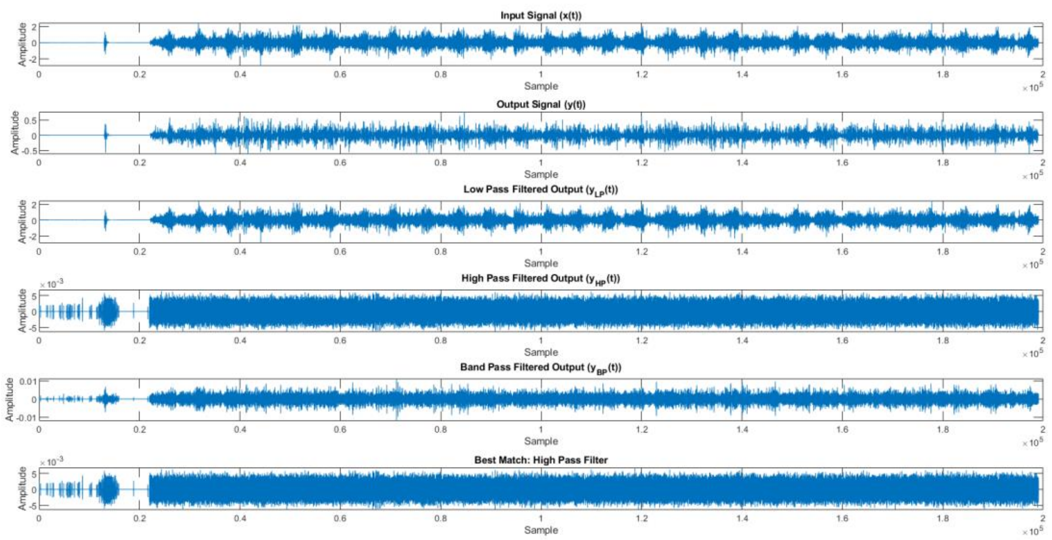


2. **High-Pass Filter Analysis 1** ([7000, 1000, 2000, 1200, 1600]):

Results

- Correlation coefficients:
  - Low Pass Filter: -10.2203%
  - High Pass Filter: 1.4445%
  - Band Pass Filter: -0.46122%
- Analysis:
  - Here, we have used sampling frequency as 7000. We observe that the correlation coefficient for the high-pass filter is positive, albeit low, indicating some alignment between the filtered output and the output signal. However, it is still lower than the correlation coefficient for the low-pass filter, suggesting that the chosen parameters might not effectively attenuate low-frequency components.

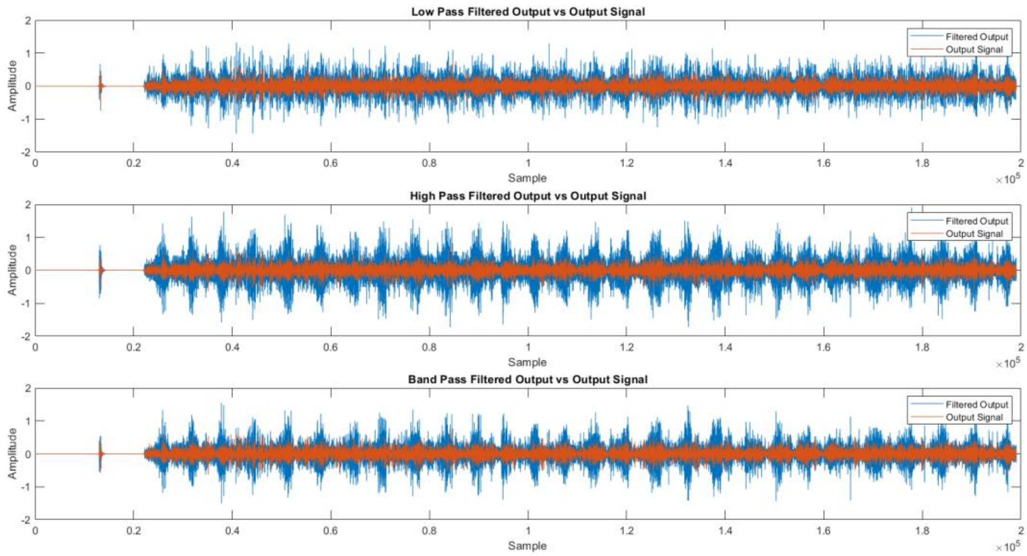


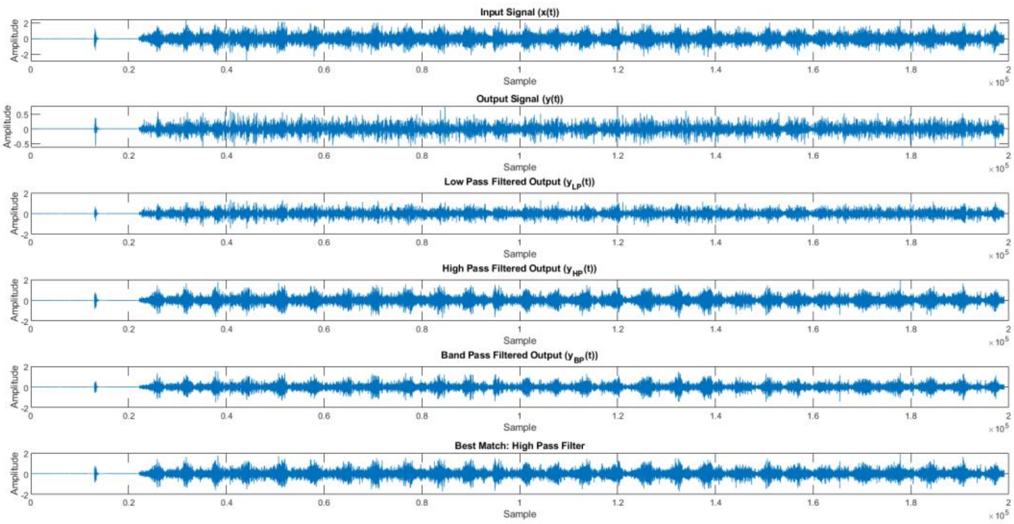


3. **High-Pass Filter Analysis 2** ([14000, 500, 500, 500, 1200]):

Results

- Correlation coefficients:
    - Low Pass Filter: -13.8446%
    - High Pass Filter: -1.4143%
    - Band Pass Filter: -1.6403%
- Analysis:
    - The correlation coefficient for the high-pass filter is negative, indicating a poor alignment between the filtered output and the output signal. This suggests that the chosen parameters might not effectively attenuate low-frequency components, leading to discrepancies between the filtered output and the desired output signal. This can be observed in the graphs following below.

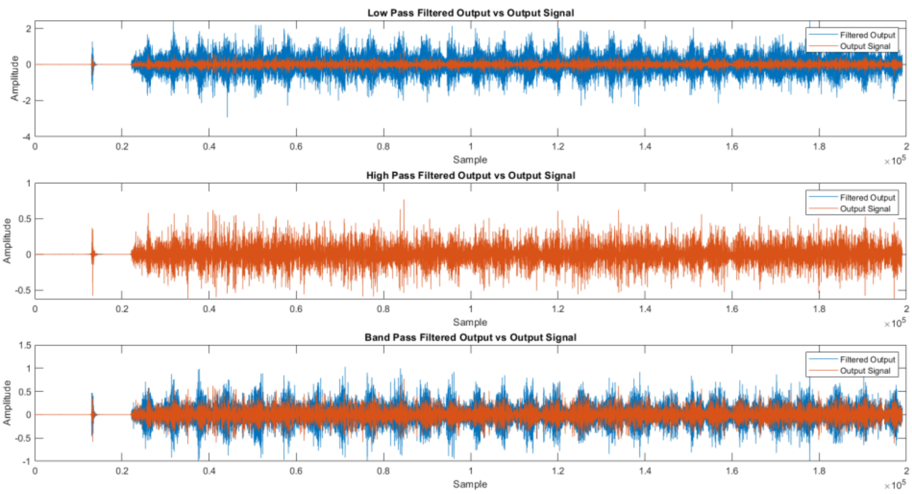


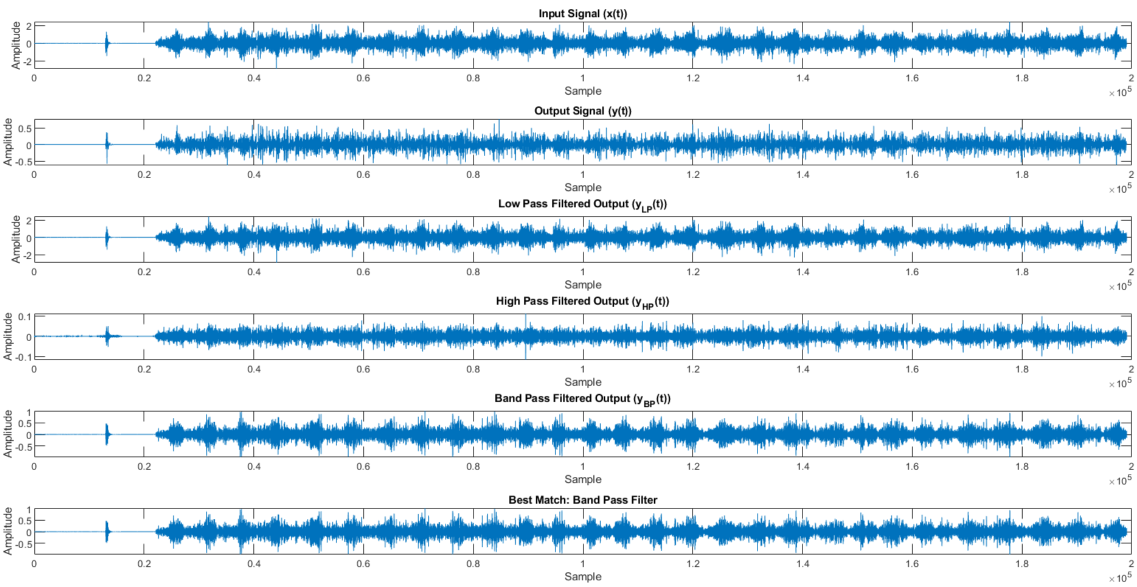


4. **Band-Pass Filter Analysis 1** ([14000, 2000, 2000, 1000, 3000]):

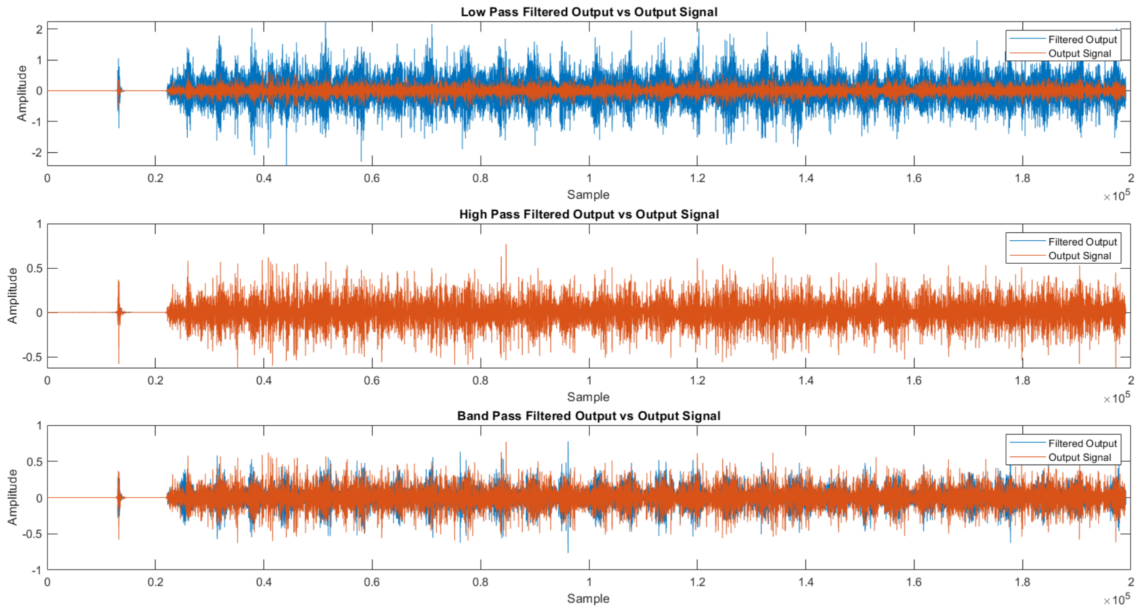
Results

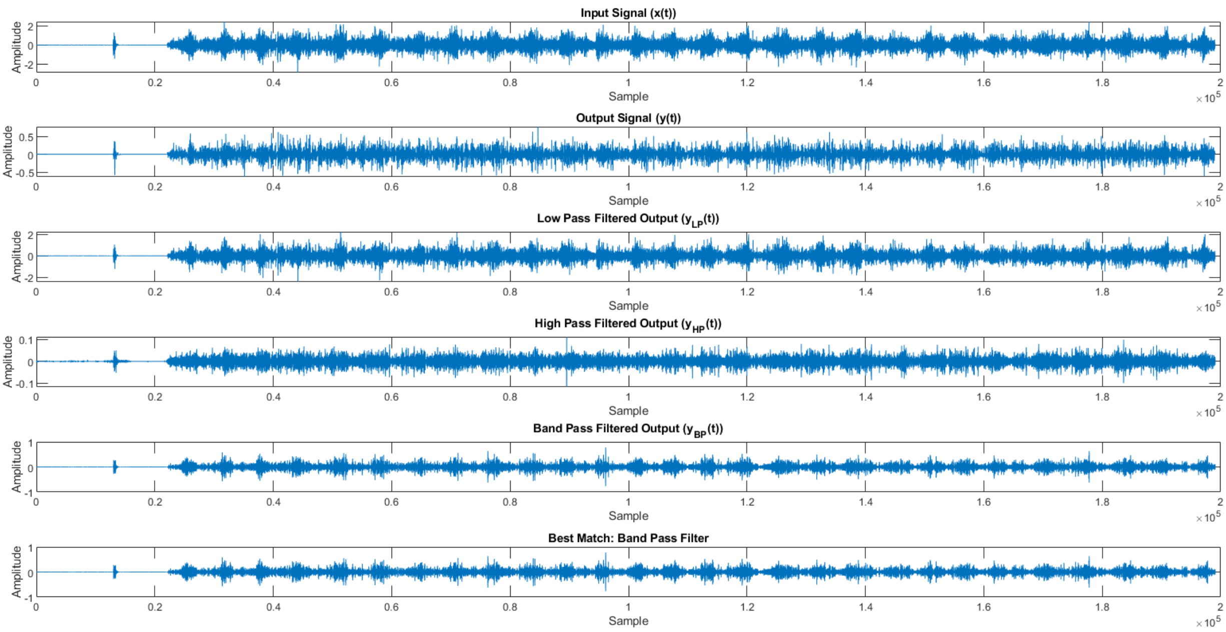
- Correlation coefficients:
  - Low Pass Filter: -10.2203%
  - High Pass Filter: -0.070131%
  - Band Pass Filter: 0.0039793%
- Analysis:
  - The correlation coefficient for the band-pass filter is close to zero, indicating a weak alignment between the filtered output and the output signal. This suggests that the chosen parameters might not effectively isolate the desired frequency band, leading to inconsistencies between the filtered output and the desired output signal.





5. **Band-Pass Filter Analysis 2** ([14000, 1000, 2000, 1200, 1600]):
    - Correlation coefficients:
        - Low Pass Filter: -11.2795%
        - High Pass Filter: -0.070131%
        - Band Pass Filter: -0.042344%
    - Analysis:
        - Similar to the previous band-pass filter analysis, the correlation coefficient for the band-pass filter is close to zero, indicating a weak alignment between the filtered output and the output signal. This suggests that the chosen parameters might not effectively isolate the desired frequency band, leading to inconsistencies between the filtered output and the desired output signal. We observed that when we used similar





parameters except when the sampling frequency was 7000, we observed that low pass filter showed higher correlation, while for 14000, i.e., double sampling frequency, it was band-pass.

Final Conclusion:

We realized that tweaking certain settings, like the sampling frequency and cutoff frequencies, had a big impact on how well the filters worked. When we got these settings just right, the filters performed better and matched the output signal more closely. It's clear that finding the sweet spot for filter settings is crucial. By experimenting more and fine-tuning these settings, we can make our filters work even better and produce more accurate results.

In this coding assignment, we set out to develop a script capable of analysing signals by comparing input and output signals after filtering. Utilizing Finite Impulse Response (FIR) filters, specifically low-pass, high-pass, and band-pass filters, our objective was to discern the type of filtering applied to the input signal. This report serves as a comprehensive documentation of our approach, implementation, and key findings derived from the analysis. Notably, we present graphical representations and results obtained from five distinct filter parameter sets to showcase the versatility of the script in matching all three types of filters to the output signal when appropriate filter parameters are employed.

We provided concise definitions for each type of filter to facilitate a clear understanding of their respective functionalities. A step-by-step methodology was outlined, encompassing the reading of input and output signals, specification of filter characteristics, filter design using MATLAB's fir1 function, convolution with the input signal, correlation-based comparison, identification of the best match, and visualization of results.

An overview of key variables used throughout the analysis was provided, explaininig their roles in the script. Subsequently, detailed analyses were conducted for each filter parameter set, including correlation coefficients and interpretive insights drawn from the results. These analyses underscored the importance of parameter selection in filter performance and alignment with the output signal.

Conclusively, through systematic experimentation and parameter adjustment, we demonstrated the script's efficacy in matching all types of filters to the output signal under varying conditions. It became evident that the success of filter matching primarily hinges on the selection of appropriate filter parameters. By fine-tuning these parameters and conducting further experimentation, we can enhance the performance of our filters and achieve more accurate results. Ultimately, this project equipped us with a deeper understanding of signal processing methodologies and the computational tools involved in analyzing and interpreting signals.