SIGNALS AND SYSTEMS

Prepared By :

AZLAAN RANJHA 392438

LAIBA JABBAR 373318

BILAL YOUNAS CHAUDHARY 389110

RANA ABDULLAH AZHAR 398569

Presented To :

MAAM ALEENA

Project

Report

Project Details

Design and Implementation of a 5-band Graphic Equalizer

Part I

The goal of this project is to design a 10-band graphic equalizer and then to implement it - first employing Simulink to check the design and then designing a GUI. Matlab can be employed to design the required filters and then Simulink can be used to implement the graphic equalizer in real time. Most commercial equalizers use either 1/3 octave or 2/3 octave bandpass filters but to keep this from becoming too large we will employ one octave bandpass filters.

Following are the design specifications for the equalizer:

1. Employing Matlab, design 5 different bandpass filters with center frequencies of 63 Hz, 250 Hz, 1000 Hz, 4000 Hz, and 16000 Hz. These center frequencies correspond to the ISO (International Standards Organization) standard for graphic equalizer center frequencies.

2. The bandwidth of each filter is the frequency difference Δf = f2 – f1, where f1 and f2 correspond to the frequencies where the gain is 3 dB less than the maximum gain at the center frequency. It also is necessary to choose f1 and f2 such that the center frequency, fc, is equal to the geometric mean of f1 and f2, i.e. fc = (f1f2) 1/2 . We also have to choose the bandwidth of each filter so that we get a flat frequency response when all filter gains are equal and added together.

3. You can use Butterworth filters; however you are free to choose the order of the filters. The Matlab help file for the Butterworth filter is the following: [B,A] = butter(N,Wn) designs an Nth order lowpass digital Butterworth filter and returns the filter coefficients in length N+1 vectors B (numerator) and A (denominator). The coefficients are listed in descending powers of z. The cutoff frequency Wn must be 0.0 < Wn < 1.0, with 1.0 corresponding to half the sample rate. If Wn is a two-element vector, Wn = [W1 W2], butter returns an order 2N bandpass filter with passband W1 < W < W2. [B,A] = butter(N,Wn,'high') designs a highpass filter. [B,A] = butter(N,Wn,'low') designs a lowpass filter. [B,A] = butter(N,Wn,'stop') is a bandstop filter if Wn = [W1 W2].

4. Write a Matlab m-file to compute the set of filter coefficients and plot the combination (sum) of all filter frequency responses. Note that you can use the 'freqz' command to easily find the frequency response of a filter defined by the filter coefficient arrays B and A. Your goal is to achieve as flat of a frequency response as you can when all the frequency response of all filters are added ± 1 dB is a good goal. Remember that the center frequency of each filter must be fixed to one of the five values given above and the upper and lower cutoff frequencies f2 & f1 must satisfy fc = (f1f2) 1/2 . Your goal is to find the Δf value for each filter that achieves a flat frequency response when all filters are combined with equal weights. [Hint: the filters should all be constant Q, where Q = fc / (f2 – f1), so once you find the right value for Q all filters should have the same Q.]

The simplified 3-band graphic equalizer is shown below, where the filters are in parallel and each one is followed by a gain (using the Matlab slider gain block). Your mixer will have 5 filters in parallel.

We would like to be able to adjust the gain of each band by ± 12 dB. Remember that 6dB corresponds to approximately a factor of 2x, so 12 dB is about 4x. So +12 dB is like multiplying by 4 and -12 dB is like multiplying by ¼.Use these values as the limits for the slider gain blocks.

One final note: The “From Multimedia File” and “To Audio Device” blocks can be found in the DSP Toolbox.

Part II

Design a GUI with the following provisions

1. A ‘load’ button that can load an audio file of your choice (Suggestion: choose a file with large frequency range e.g a symphony).

2. Display for the input and output signals.

3. Display for the input and output spectrum.

4. Adjustable gain sliders for the filters.

5. A ‘play’ button that can playback the output file.

Introduction

The project aims to design and implement a 5-band graphic equalizer in two parts. In Part I, the focus is on crafting five bandpass filters with specific center frequencies, adhering to ISO standards. Matlab and Simulink are employed for design validation and real-time implementation. The use of Butterworth filters with adjustable orders is recommended. The goal is to achieve a flat frequency response when combining all filters with equal weights, ensuring constant Q. Part II involves designing a user-friendly GUI with features such as a 'load' button for audio file selection, input/output signal displays, adjustable gain sliders, and a 'play' button for playback, facilitating intuitive audio customization.

Objectives

1. Designing of Filters on Matlab
2. Implementation of those filters using Simulink
3. Creating a GUI for our Audio Equaliser

Filter Designing using MATLAB

In this project conducted using MATLAB, we aimed to design a 5-band graphic equalizer. The process involved specifying center frequencies for each band and determining a Q factor. As we have to design a single octave filter so we will be using a Q factor of $\sqrt{2}$. Utilizing MATLAB's Butterworth filter design, octave bandpass filters were created for each center frequency. The higher frequency is just double the lower frequency in each case. The code then systematically plots the individual frequency responses of each band and their combined response, providing a visual representation of the equalizer's behavior. Importantly, this MATLAB implementation serves as a crucial step before transitioning to Simulink. Once the filters are designed and optimized in MATLAB, they are exported to Simulink for real-time implementation. The individual functions in the code handle the calculation of lower and upper cutoff frequencies, the design of Butterworth bandpass filters, and the plotting of frequency responses. This MATLAB-to-Simulink workflow ensures a seamless integration of the designed filters into a real-time graphic equalizer system.

Code:

```matlab
% Define center frequencies (Hz)
center_frequencies = [63, 250, 1000, 4000, 16000];


% Define Q factor
Q = sqrt(2);


% Define sampling frequency (Fs)
Fs = 62000;


% Preallocate arrays for filter coefficients
B = cell(1, length(center_frequencies));
A = cell(1, length(center_frequencies));


% Design octave bandpass filters for each center frequency
for i = 1:length(center_frequencies)
    fc = center_frequencies(i);

    % Calculate lower and upper cutoff frequencies for octave bandpass filter
    f1 = fc / Q;
    f2 = 2 * f1;


    % Design Butterworth bandpass filter with Q factor
    [B{i}, A{i}] = butter(3, [f1, f2]/(Fs/2), 'bandpass');
end
```

```
% Plot individual frequency responses of all bands
figure;
for i = 1:length(center_frequencies)
    [H, F] = freqz(B{i}, A{i}, 1024, Fs);
    plot(F, 20*log10(abs(H)), 'LineWidth', 1.5);
    hold on;
end


% Plot the combined frequency response of all filters
combined_response = zeros(1024, 1);
for i = 1:length(center_frequencies)
    [H, F] = freqz(B{i}, A{i}, 1024, Fs);
    combined_response = combined_response + abs(H).^2; % Accumulate squared
magnitude
end


% Normalize the combined response
combined_response = 20*log10(sqrt(combined_response/length(center_frequencies)));


% Plot the normalized combined response
plot(F, combined_response, 'LineWidth', 1.5);


title('Combined Frequency Response of 1-Octave Bandpass Filters');
xlabel('Frequency (Hz)');
ylabel('Gain (dB)');
legend('Band 1', 'Band 2', 'Band 3', 'Band 4', 'Band 5', 'Combined', 'Location',
'northeastoutside');
hold off;

%grid on;
% Display additional filter information
fprintf('Filter Information:\n');
```

```
Filter Information:
```

```
for i = 1:length(center_frequencies)
    f1 = center_frequencies(i) / Q;
    f2 = 2 * f1;

    fprintf('Band %d - Center Frequency: %d Hz, Lower Frequency: %.2f Hz, Upper
Frequency: %.2f Hz, Bandwidth: %.2f Hz\n', i, center_frequencies(i), f1, f2, f2-
f1);
end
```

Output:

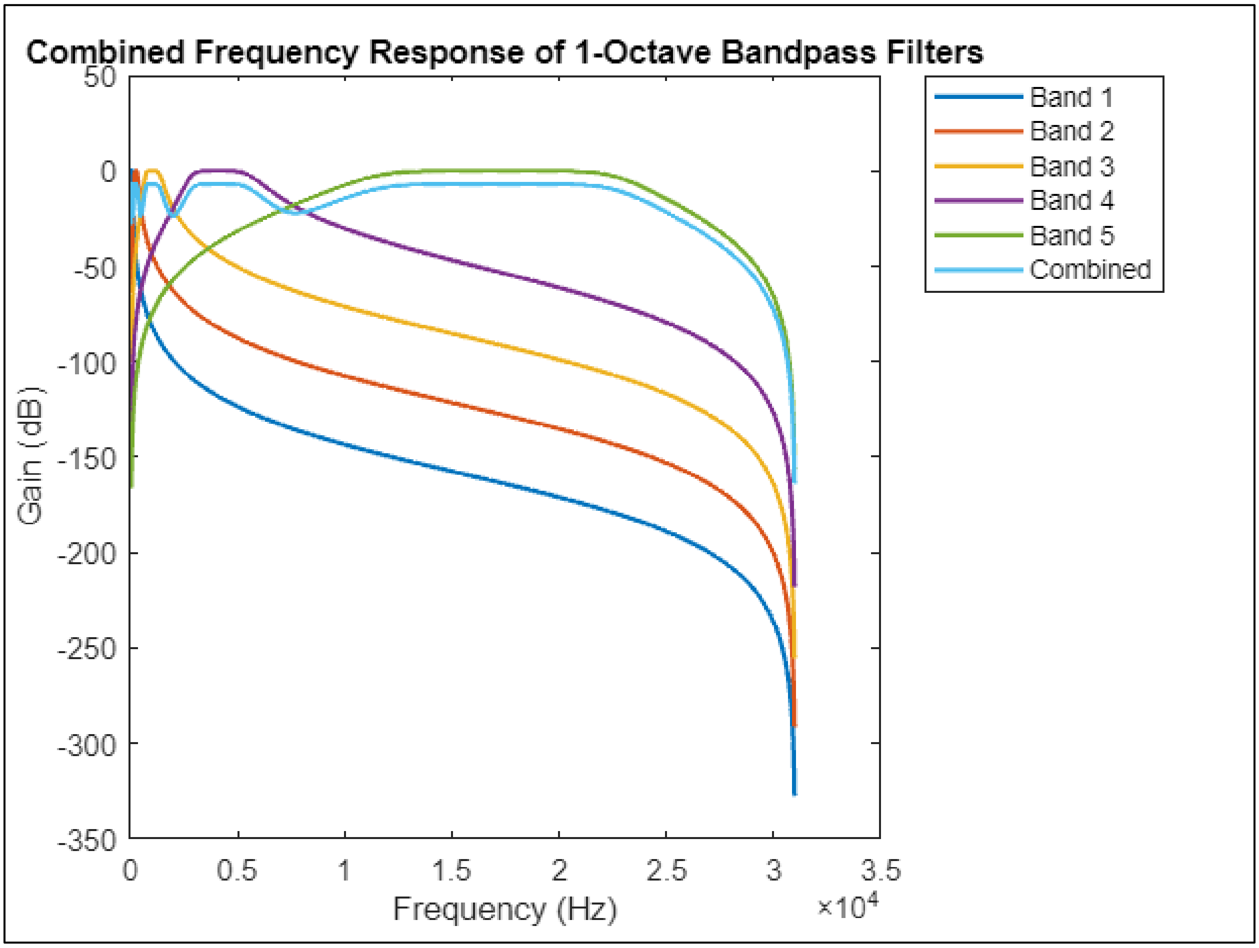


Figure 1: Combined Frequency Response of our 5 Band Filter

Values of Upper and Lower Frequencies Calculated and Printed by our Code:

```
Band 1 - Center Frequency: 63 Hz, Lower Frequency: 44.55 Hz, Upper Frequency:
89.10 Hz, Bandwidth: 44.55 Hz
Band 2 - Center Frequency: 250 Hz, Lower Frequency: 176.78 Hz, Upper
Frequency: 353.55 Hz, Bandwidth: 176.78 Hz
Band 3 - Center Frequency: 1000 Hz, Lower Frequency: 707.11 Hz, Upper
Frequency: 1414.21 Hz, Bandwidth: 707.11 Hz
Band 4 - Center Frequency: 4000 Hz, Lower Frequency: 2828.43 Hz, Upper
Frequency: 5656.85 Hz, Bandwidth: 2828.43 Hz
Band 5 - Center Frequency: 16000 Hz, Lower Frequency: 11313.71 Hz, Upper
Frequency: 22627.42 Hz, Bandwidth: 11313.71 Hz
```

Simulink Circuit and Filters

Simulink Schematic:

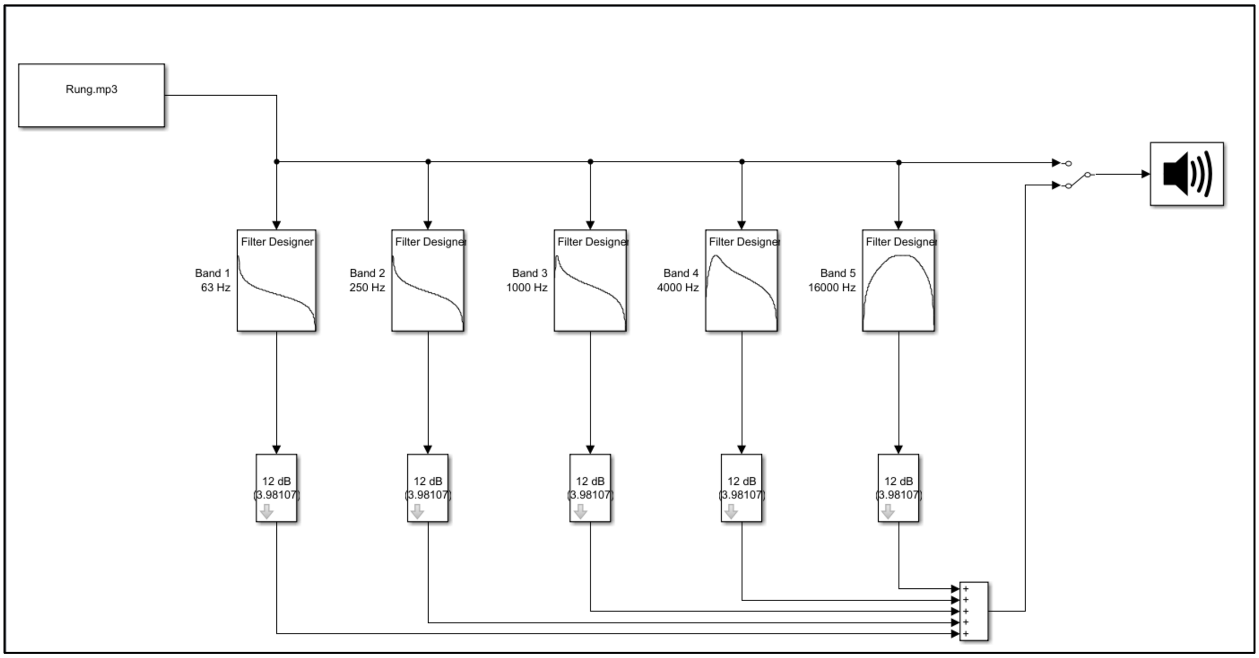
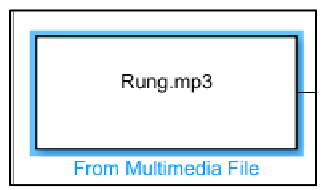


Figure 2: Simulink Schematic of our Audio Equaliser

We have used the following blocks in our Simulink Schematic:

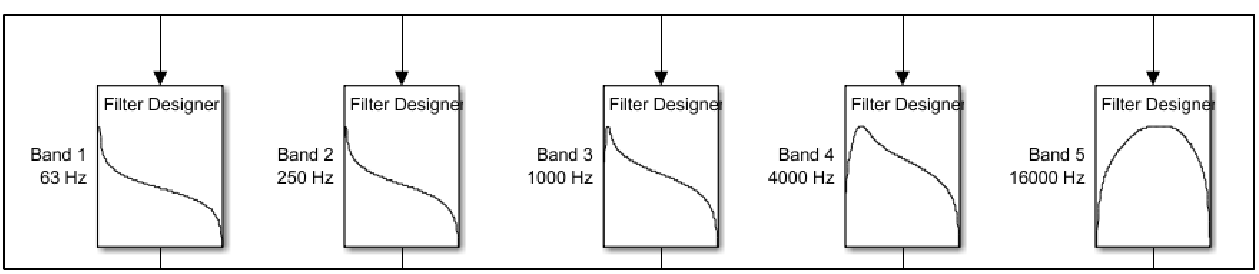
1. **From Multimedia File Block:**



The "From Multimedia File" block in Simulink is a vital tool for importing audio data into simulations. It serves as an input interface, facilitating the seamless integration of external audio files into Simulink models. This block is essential for testing and analyzing systems involving audio processing within the Simulink environment, enhancing the versatility of modeling and simulation tasks. It is a part of the DSP Toolbox

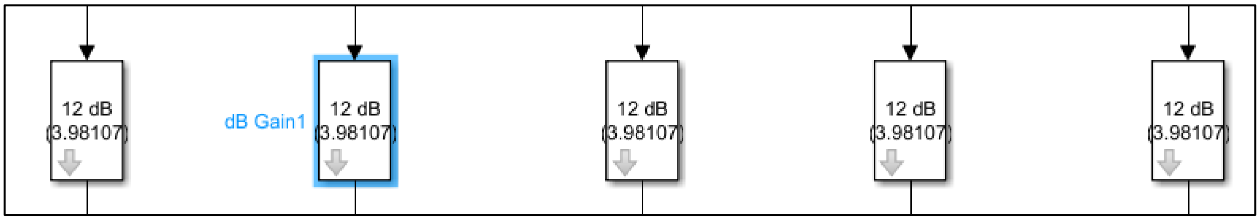
2. **Filter Designer Block:**

The "Filter Designer" block in Simulink is a user-friendly interface for creating and customizing digital filters. It enables real-time adjustments of filter specifications, including type, order, and cutoff frequencies.

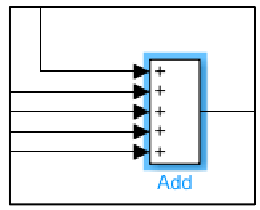


Supporting various filter designs, such as lowpass and highpass, this block is essential for efficient digital filter design within Simulink simulations.

3. **dB Gain Block:**

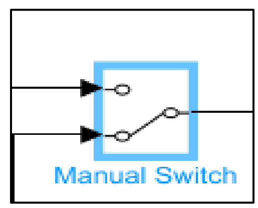


The "dB Gain" block in Simulink is a crucial component for adjusting signal gain in decibels. This block simplifies the process of scaling signal amplitudes, providing an efficient way to apply logarithmic gain adjustments within Simulink simulations.



4. **Add Block:**

The "Add" block in Simulink is a core element for mathematical operations in a model. It enables the summation of multiple input signals, providing a versatile tool for combining and manipulating signals within a simulation. The block enhances the modularity and flexibility of Simulink models, allowing users to perform additive operations and create complex signal processing or control system models efficiently.



5. **Manual Switch Block:**

The "Manual Switch" block in Simulink enables users to manually toggle between multiple input signals, controlling signal flow within a model. This block is valuable for scenarios requiring dynamic signal routing or conditional switching. By interacting with the "Manual Switch," users can efficiently simulate different scenarios and test the impact of various signal pathways in their models, enhancing adaptability and versatility in Simulink simulations.

6. **Audio Device Writer Block:**

The "Audio Device Writer" block in Simulink facilitates audio output in simulation models. It allows users to stream simulated audio signals directly to audio devices for real-time auditory feedback during simulations. By connecting this block to the desired audio source, users can integrate and test audio processing algorithms or control systems with ease. The "Audio Device Writer" enhances Simulink simulations by providing a practical way to evaluate the real-world impact of models through audible output.

Now let us look at the designed filters of our schematic:

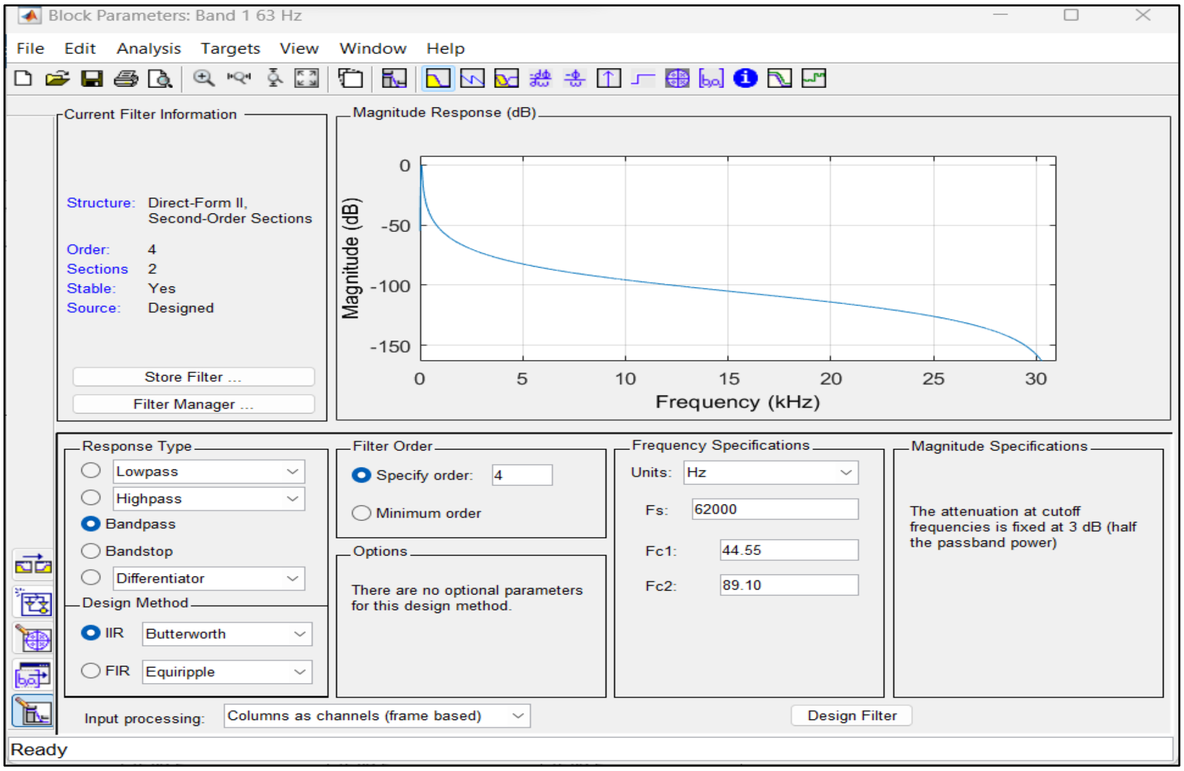


Figure 3: 63 Hz BandPass Filter

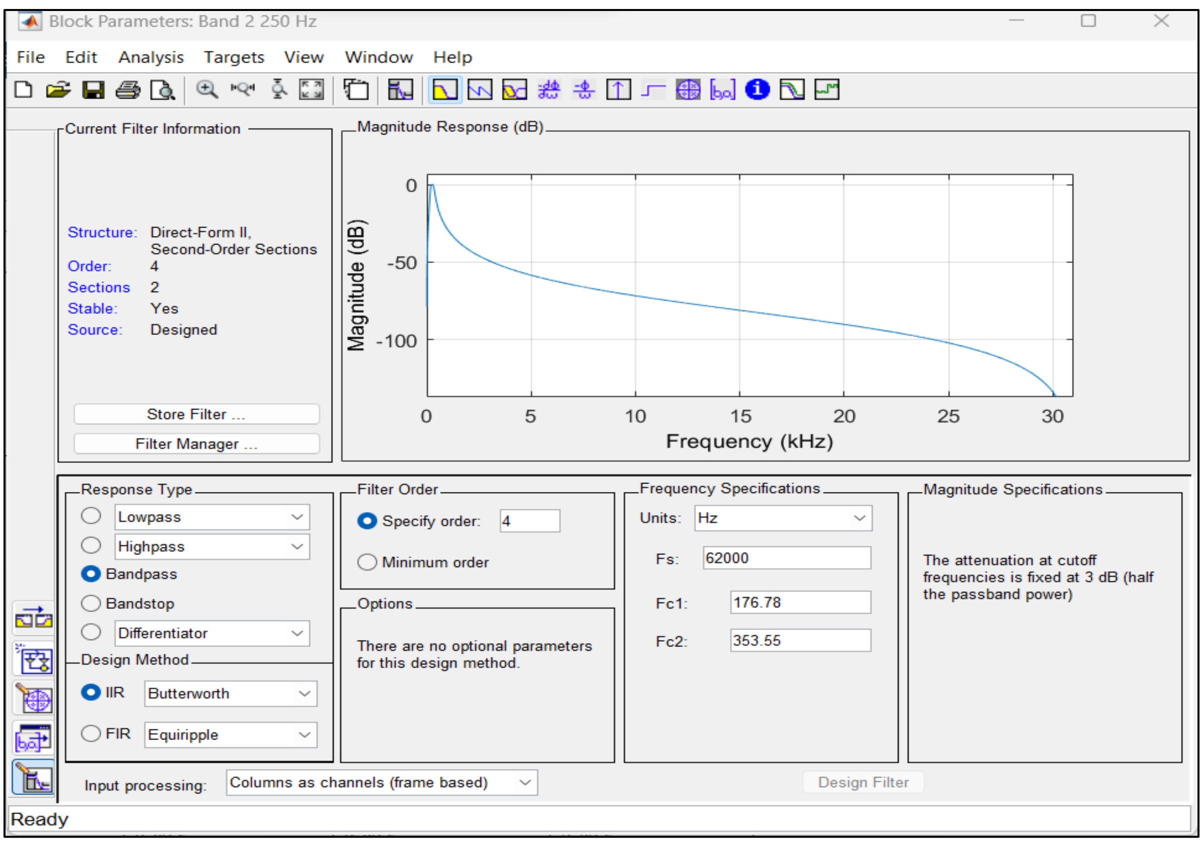


Figure 4: 250 Hz BandPass Filter

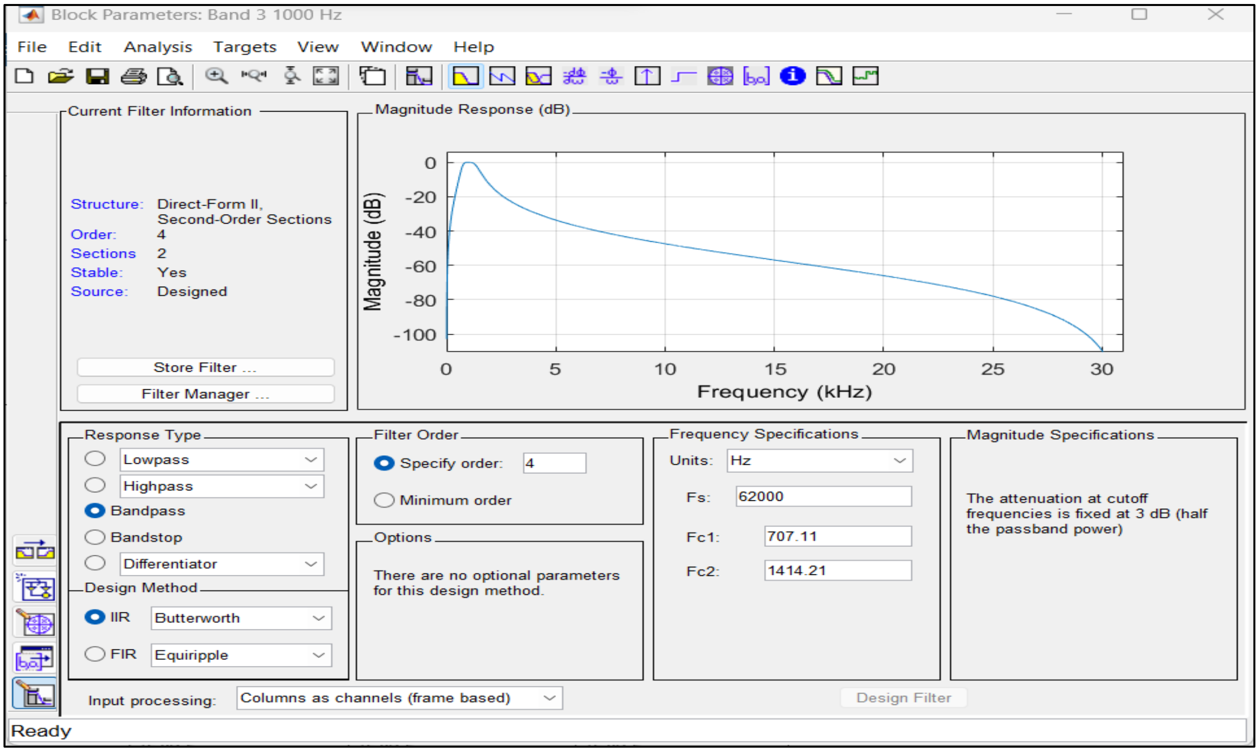


Figure 5: 1000 Hz BandPass Filter

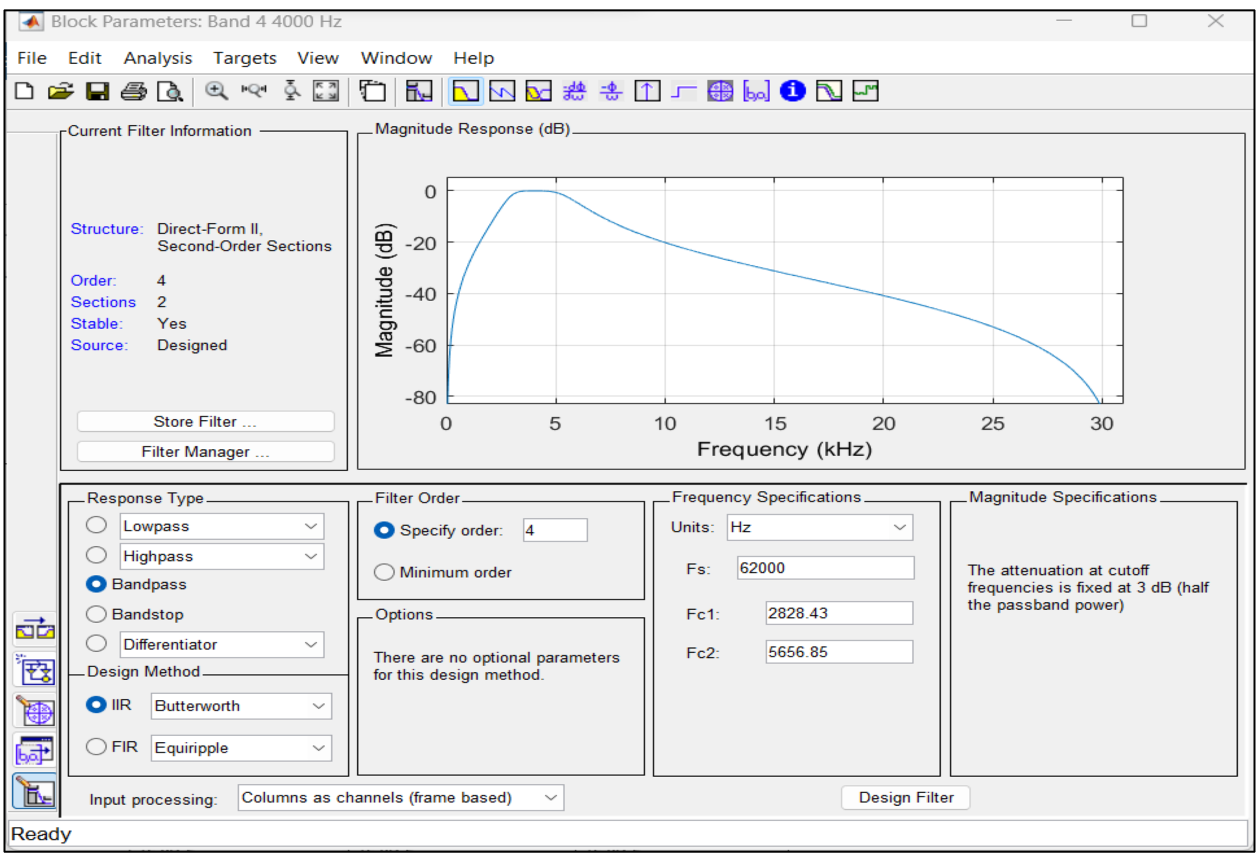


Figure 6: 4000 Hz BandPass Filter

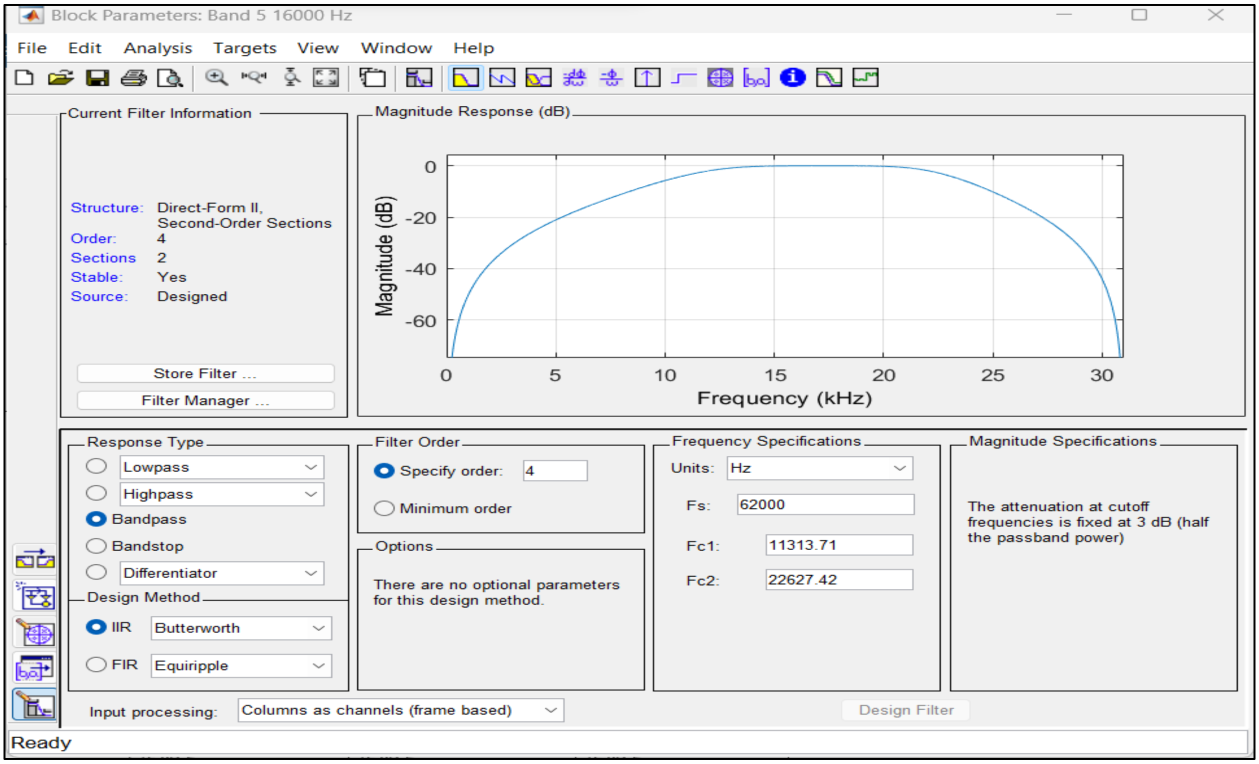


Figure 7: 16000 Hz BandPass Filter

GUI Code

```
classdef Project_GUI_Code < matlab.apps.AppBase

    % Properties that correspond to app components
    properties (Access = public)
        UIFigure                matlab.ui.Figure
        UIAxesBackground        matlab.ui.control.UIAxes
        TrackDropDown           matlab.ui.control.DropDown
        SongSelectDropDownLabel   matlab.ui.control.Label
        PLOTButton              matlab.ui.control.Button
        RESETButton             matlab.ui.control.Button
        PLAYButton              matlab.ui.control.Button
        LOADButton              matlab.ui.control.Button
        EditField_5             matlab.ui.control.EditField
        Slider_5                matlab.ui.control.Slider
        Band5fc16000HzLabel     matlab.ui.control.Label
        EditField_4             matlab.ui.control.EditField
        Slider_4                matlab.ui.control.Slider
        Band4fc4000HzLabel      matlab.ui.control.Label
        EditField_3             matlab.ui.control.EditField
        Slider_3                matlab.ui.control.Slider
```

```
        Band3fc1000HzLabel   matlab.ui.control.Label
        EditField_2          matlab.ui.control.EditField
        Slider_2             matlab.ui.control.Slider
        Band2fc250HzLabel    matlab.ui.control.Label
        EditField_1          matlab.ui.control.EditField
        Band1fc63HzLabel     matlab.ui.control.Label
        Slider_1             matlab.ui.control.Slider
        UIAxes5              matlab.ui.control.UIAxes
        UIAxes4              matlab.ui.control.UIAxes
        UIAxes3              matlab.ui.control.UIAxes
        UIAxes2              matlab.ui.control.UIAxes
        UIAxes1              matlab.ui.control.UIAxes

        % Additional properties for storing data
        audioFilePath
        audioSignal
        sampleRate
        fileReader
        deviceWriter
    end

    properties (Access = private)
        fg = [63,250,1000,4000,16000];
        fk = [63, 70.8, 250, 282, 1000, 1120, 4000, 4470, 16000, 17800];
        fs = 44100;
        wn = 2*pi*[63, 66.9, 70.8, 75, 250, 266, 282, 299, 1000, 1060, 1120, 1180,
4000, 4220, 4470, 4730, 16000, 16800, 17800, 18800];
        isStop = 0;
        isPlay = 0;
    end

    % Callbacks that handle component events
    methods (Access = private)

        function a = den(app,k,Fs)

            thetak = 2*pi*app.fk(k)/Fs;

            if k>1 && k<10

                dthetak = (2*pi*app.fk(k+1)/Fs-2*pi*app.fk(k-1)/Fs)/2;

            elseif k == 1

                dthetak = 2*pi*app.fk(2)/Fs-2*pi*app.fk(1)/Fs;
            else

                dthetak = 2*pi*app.fk(10)/Fs-2*pi*app.fk(9)/Fs;
            end

            pk = exp(-dthetak/2);
            a = [1 -2*pk*cos(thetak) pk^2];
        end

        function Mrplus = Mrp(app, Fs)
```

```
            M = zeros(20, 21);
            M(:, 22) = ones(20, 1);
            sqW = Weight(app, app.Slider_1.Value, app.Slider_2.Value,
app.Slider_3.Value, app.Slider_4.Value, app.Slider_5.Value);

            for n = 1:20
                for k = 1:10
                    M(n, 2 * k - 1) = 1 / (den(app, k, Fs) * [1; exp(-app.wn(n) / Fs
* 1i); exp(-2 * app.wn(n) / Fs * 1i)]);
                    M(n, 2 * k) = exp(-app.wn(n) / Fs * 1i) / (den(app, k, Fs) * [1;
exp(-app.wn(n) / Fs * 1i); exp(-2 * app.wn(n) / Fs * 1i)]);
                end
                M(n, :) = M(n, :) * sqW(n);
            end

            Mr = [real(M); imag(M)];

            % Use the pseudo-inverse to improve stability
            Mrplus = pinv(transpose(Mr) * Mr) * transpose(Mr);
        end


        %Calculation of the target response vector
        function htr = target(app,G1,G2,G3,G4,G5)

            y = 10.^(1/20*pchip([-flip(app.fg) app.fg],[flip([G1,G2,G3,G4,G5])
[G1,G2,G3,G4,G5]],linspace(-app.fs/2,app.fs/2,2^16)))';

            phase = unwrap(imag(-hilbert(log(y))));
            % Adjust the range based on the actual length of the 'phase' vector
            phase_start = round(32769 * length(phase) / 2^16);
            phase_end = round(64124 * length(phase) / 2^16);
            phase = phase(phase_start:phase_end);

            i = 1;
            fi = zeros(1,20);

            for w = app.wn/(2*pi)
                if round(w*length(phase)/21100) > length(phase)
                    fi(i) = phase(length(phase));
                else
                    fi(i) = phase(round(w*length(phase)/21100));
                end
                i=i+1;
            end

            htr = [real(exp(1i*fi'));imag(exp(1i*fi'))];

        end

        %Calculation of the optimal numerator coefficients
        function popt = num(~,htr,Mrplus)
            popt = Mrplus*htr;
        end
```

```
        %Filtering process algorithm
        function yk = filterNew(app,bWithIndex,xk1,ybuffer,xbuffer,Fs,n)
            yk =
filter(bWithIndex',den(app,n,Fs),xk1,filtic(bWithIndex',den(app,n,Fs),ybuffer,xbuffer
));
        end

        %Calculation of the Weighting factors
        function sqW = Weight(app,G1,G2,G3,G4,G5)
            ht = 10.^(1/20*pchip([app.fg],[G1,G2,G3,G4,G5],app.wn/(2*pi)))';
            sqW1 = zeros(20,1);
            for i = 1:20
                sqW1(i) = 1/ht(i);
            end
            sqW = sqW1;
        end

        % Button pushed function: LOADButton
        function LOADButtonPushed(app, ~)
            % Set the path to the desired directory
            folderPath = 'C:\Users\Azlaan\Music\';

            % List MP3 files
            mp3Files = struct2cell(dir(fullfile(folderPath, '*.mp3')));
            mp3Files = mp3Files(1, :);

            % List WAV files
            wavFiles = struct2cell(dir(fullfile(folderPath, '*.wav')));
            wavFiles = wavFiles(1, :);

            % Combine MP3 and WAV files into a single list
            audioFiles = [mp3Files, wavFiles];

            % Update app.TrackDropDown.Items
            app.TrackDropDown.Items = audioFiles;

            % Check if the list is empty and show a message if true
            if isempty(app.TrackDropDown.Items)
                uialert(app.UIFigure, ...
                    ['Your current folder does not contain any audio files'], ...
                    'Info', 'Icon', 'info');
            end
        end

        % Button pushed function: PLOTButton
        function PLOTButtonPushed(app, event)
            % Get the selected MP3 file name from the dropdown
            selectedTrack = app.TrackDropDown.Value;

            % Check if a song is selected
            if isempty(selectedTrack)
                disp('Please select a song from the dropdown.');
                return;
            end
```

```
            % Construct the full path to the selected MP3 file
            filePath = fullfile('C:\Users\Azlaan\Music\', selectedTrack);

            % Read the audio signal from the selected MP3 file
            try
                [app.audioSignal, app.sampleRate] = audioread(filePath);
            catch
                disp('Error loading the selected song.');
                return;
            end

            if isempty(app.audioSignal)
                disp('Please load a song first.');
                return;
            end
            % Design and apply filters here
            center_frequencies = [63, 250, 1000, 4000, 16000];
            Q = sqrt(2);
            desired_order = 3;
            Fs = 48000;

            % Preallocate arrays for filter coefficients
            B = cell(1, length(center_frequencies));
            A = cell(1, length(center_frequencies));
            f1 = [44.55, 176.78, 707.11, 2828.43, 11313.71];
            f2 = [89.10, 353.55, 1414.21, 5656.85, 22627.42];

            % Design Butterworth filters
            for i = 1:length(center_frequencies)
                fc = center_frequencies(i);
                [B{i}, A{i}] = butter(desired_order, [f1(i), f2(i)]/(Fs/2),
'bandpass');
            end

            % Apply filters to the input signal and multiply each band by the
corresponding gain
            filtered_signals = cell(1, length(center_frequencies));
            combined_output = zeros(size(app.audioSignal));

            for i = 1:length(center_frequencies)
                % Apply filter
                filtered_signals{i} = filter(B{i}, A{i}, app.audioSignal);

                % Multiply by gain from the corresponding slider
                gain = app.(['Slider_', num2str(i)]).Value; % Access slider value
dynamically
                filtered_signals{i} = filtered_signals{i} * 10^(gain/20); % Convert
dB to linear scale

                % Sum the adjusted signals
                combined_output = combined_output + filtered_signals{i};
            end

            % Plot the original signal
            t_original = (0:length(app.audioSignal)-1) / app.sampleRate;
```

```
            clf(app.UIAxes1)
            plot(app.UIAxes1, t_original, app.audioSignal);
            title(app.UIAxes1, 'Original Signal');
            xlabel(app.UIAxes1, 'Time (s)');
            ylabel(app.UIAxes1, 'Amplitude');
            axis(app.UIAxes1, 'tight');

            % Plot the combined adjusted signal on UIAxes2
            t_adjusted = (0:length(combined_output)-1) / app.sampleRate;
            clf(app.UIAxes2)
            plot(app.UIAxes2, t_adjusted, combined_output);
            title(app.UIAxes2, 'Combined Adjusted Signal');
            xlabel(app.UIAxes2, 'Time (s)');
            ylabel(app.UIAxes2, 'Amplitude');
            axis(app.UIAxes2, 'tight');

            % Plot the input spectrum on UIAxes3
            Audio_len = length(app.audioSignal);
            FFT_audio = fft(app.audioSignal);
            P2_audio = abs(FFT_audio / Audio_len);
            P1_audio = P2_audio(1:Audio_len/2+1);
            P1_audio(2:end-1) = 2 * P1_audio(2:end-1);
            freq_audio = app.sampleRate * (0:(Audio_len/2)) / Audio_len;
            plot(app.UIAxes3, freq_audio, P1_audio);
            title(app.UIAxes3, 'Input Spectrum');
            xlabel(app.UIAxes3, 'Frequency (Hz)');
            ylabel(app.UIAxes3, 'Amplitude');
            axis(app.UIAxes3, 'tight');

            % Plot the output spectrum on UIAxes4
            Audio_len_combined = length(combined_output);
            FFT_combined = fft(combined_output);
            P2_combined = abs(FFT_combined / Audio_len_combined);
            P1_combined = P2_combined(1:Audio_len_combined/2+1);
            P1_combined(2:end-1) = 2 * P1_combined(2:end-1);
            freq_combined = app.sampleRate * (0:(Audio_len_combined/2)) /
Audio_len_combined;
            plot(app.UIAxes4, freq_combined, P1_combined);
            title(app.UIAxes4, 'Output Spectrum');
            xlabel(app.UIAxes4, 'Frequency (Hz)');
            ylabel(app.UIAxes4, 'Amplitude');
            axis(app.UIAxes4, 'tight');

            % Plot the characteristic filter response on UIAxes5
            combined_response = zeros(size(app.audioSignal));

            for i = 1:length(center_frequencies)
                % Calculate the frequency response of the filter
                [H, F] = freqz(B{i}, A{i}, length(app.audioSignal), app.sampleRate);

                % Multiply by gain from the corresponding slider
                gain = app.(['Slider_', num2str(i)]).Value; % Access slider value
dynamically
                H = H * 10^(gain/20); % Convert dB to linear scale
```

```
            % Sum the adjusted responses
            combined_response = combined_response + abs(H);
        end

        % Plot the characteristic filter response on UIAxes5
        clf(app.UIAxes5);
        plot(app.UIAxes5, F, combined_response, 'b');
        title(app.UIAxes5, 'Characteristic Filter Response');
        xlabel(app.UIAxes5, 'Frequency (Hz)');
        ylabel(app.UIAxes5, 'Magnitude');
        axis(app.UIAxes5, 'tight');
    end

    % Value changed function: Slider_1
    function Slider_1ValueChanged(app, event)
        % Get the current value of the slider
        sliderValue = app.Slider_1.Value;

        % Display the value in the edit field
        app.EditField_1.Value = num2str(sliderValue);
    end

    % Value changed function: Slider_2
    function Slider_2ValueChanged(app, event)
        % Get the current value of the slider
        sliderValue = app.Slider_2.Value;

        % Display the value in the edit field
        app.EditField_2.Value = num2str(sliderValue);
    end

    % Value changed function: Slider_3
    function Slider_3ValueChanged(app, event)
        % Get the current value of the slider
        sliderValue = app.Slider_3.Value;

        % Display the value in the edit field
        app.EditField_3.Value = num2str(sliderValue);
    end

    % Value changed function: Slider_4
    function Slider_4ValueChanged(app, event)
        % Get the current value of the slider
        sliderValue = app.Slider_4.Value;

        % Display the value in the edit field
        app.EditField_4.Value = num2str(sliderValue);
    end

    % Value changed function: Slider_5
    function Slider_5ValueChanged(app, event)
        % Get the current value of the slider
        sliderValue = app.Slider_5.Value;

        % Display the value in the edit field
```

```
            app.EditField_5.Value = num2str(sliderValue);
        end

        % Value changed function: EditField_1
        % Value changed function: EditField_1
        function EditField_1ValueChanged(app, event)
            editfieldvalue = str2double(app.EditField_1.Value);

            % Check if the value is within the slider limits
            editfieldvalue = max(min(editfieldvalue, app.Slider_1.Limits(2)),
    app.Slider_1.Limits(1));

            % Update the corresponding slider
            app.Slider_1.Value = editfieldvalue;
        end

        % Value changed function: EditField_2
        function EditField_2ValueChanged(app, event)
            editfieldvalue = str2double(app.EditField_2.Value);
            editfieldvalue = max(min(editfieldvalue, app.Slider_2.Limits(2)),
    app.Slider_2.Limits(1));
            app.Slider_2.Value = editfieldvalue;
        end

        % Value changed function: EditField_3
        function EditField_3ValueChanged(app, event)
            editfieldvalue = str2double(app.EditField_3.Value);
            editfieldvalue = max(min(editfieldvalue, app.Slider_3.Limits(2)),
    app.Slider_3.Limits(1));
            app.Slider_3.Value = editfieldvalue;
        end

        % Value changed function: EditField_4
        function EditField_4ValueChanged(app, event)
            editfieldvalue = str2double(app.EditField_4.Value);
            editfieldvalue = max(min(editfieldvalue, app.Slider_4.Limits(2)),
    app.Slider_4.Limits(1));
            app.Slider_4.Value = editfieldvalue;
        end

        % Value changed function: EditField_5
        function EditField_5ValueChanged(app, event)
            editfieldvalue = str2double(app.EditField_5.Value);
            editfieldvalue = max(min(editfieldvalue, app.Slider_5.Limits(2)),
    app.Slider_5.Limits(1));
            app.Slider_5.Value = editfieldvalue;
        end

        % Button pushed function: PLAYButton
        function PLAYButtonPushed(app, ~)
            app.audioSignal = app.TrackDropDown.Value;

            % Check if a song is loaded
            if isempty(app.audioSignal)
                disp('Please load a song first.');
```

```
            return;

        elseif strcmp(app.PLAYButton.Text,'PLAY') && app.isPlay == 0

            % Specify the folder path where audio files are stored
            folderPath = 'C:\Users\Azlaan\Music\';

            % Construct the full path to the selected audio file
            selectedFile = fullfile(folderPath, char(app.TrackDropDown.Value));

            % Acquiring the audio file
            app.fileReader = dsp.AudioFileReader(selectedFile, 'SamplesPerFrame',
1024);
            app.deviceWriter = audioDeviceWriter('SampleRate',
app.fileReader.SampleRate);

            app.PLAYButton.Text = 'PAUSE';
            app.isPlay = 1;
            app.sampleRate = app.fileReader.SampleRate;
            Fs = app.fs;

            %Initializing the delays
            xbuffer1 = 0;
            xbuffer2 = 0;
            ybuffer1 = zeros(10,3);
            ybuffer2 = zeros(10,3);

            S1 = app.Slider_1.Value;
            S2 = app.Slider_2.Value;
            S3 = app.Slider_3.Value;
            S4 = app.Slider_4.Value;
            S5 = app.Slider_5.Value;

            Mrplus = Mrp(app,Fs);

            b = num(app,target(app,S1,S2,S3,S4,S5),Mrplus);

            dF = Fs/1024;
            f = -Fs/2:dF:Fs/2-dF;

            i = 0;

            %Playback loop
            while ~isDone(app.fileReader)
                %Acquiring the succeeding frame
                xk = app.fileReader();

                if length(xk(1,:))~=2
                    xk = [xk,xk];
                    xk1 = xk(:,1)';
                    xk2 = xk(:,2)';
                else
                    xk1 = xk(:,1)';
                    xk2 = xk(:,2)';
                end
```

```
                    if strcmp(app.PLAYButton.Text,'PLAY') == 1
                        %Pause loop
                        while strcmp(app.PLAYButton.Text,'PLAY') == 1 && ...
                                app.isStop == 0
                            pause(1);
                        end
                    end

                    pause(0);

                    %Checking if slider configuration changed
                    if app.Slider_1.Value ~= S1 || app.Slider_2.Value ~= S2 ||
app.Slider_3.Value ~= S3 || S4 ~= app.Slider_4.Value ||  S5 ~= app.Slider_5.Value

                        S1 = app.Slider_1.Value;
                        S2 = app.Slider_2.Value;
                        S3 = app.Slider_3.Value;
                        S4 = app.Slider_4.Value;
                        S5 = app.Slider_5.Value;

                        %Calculating the new filters
                        Mrplus = Mrp(app,Fs);
                        b = num(app,target(app,S1,S2,S3,S4,S5), Mrplus);
                    end

                    %Filtering process
                    for n=1:11
                        if n<11
                            ykNew1(n,:) = filterNew(app,b((2*n-
1):(2*n)),xk1,ybuffer1(n,:),xbuffer1,Fs,n);
                            ykNew2(n,:) = filterNew(app,b((2*n-
1):(2*n)),xk2,ybuffer2(n,:),xbuffer2,Fs,n);
                        else
                            ykNew1(n,:) = xk1*b(22);
                            ykNew2(n,:) = xk2*b(22);
                        end

                    end

                    yk1=0;
                    yk2=0;

                    for n=1:11
                        yk1=yk1 + ykNew1(n,:);

                        yk2=yk2 + ykNew2(n,:);
                    end

                    %Playback of frame
                    app.deviceWriter([0.25*yk1',0.25*yk2']);

                    %Delay updates
                    xbuffer1 = flip(xk1(length(xk1)-1:length(xk1)));
                    xbuffer2 = flip(xk2(length(xk2)-1:length(xk2)));
```

```
                for n=1:10
                    ybuffer1(n,:)=flip(ykNew1(n,...
                        (length(ykNew1(n,:))-2):(length(ykNew1(n,:)))));

                    ybuffer2(n,:)=flip(ykNew2(n,...
                        (length(ykNew2(n,:))-2):(length(ykNew2(n,:)))));
                end


                if app.isStop == 1
                    release(app.fileReader);
                    release(app.deviceWriter);
                    app.PLAYButton.Text = 'PLAY';
                    app.isPlay = 0;
                    app.isStop = 0;
                end

                i = i+1;
            end


            release(app.fileReader);
            release(app.deviceWriter);

            app.PLAYButton.Text = 'PLAY';
            app.isPlay = 0;

        elseif strcmp(app.PLAYButton.Text,'PLAY') && ...
                app.isPlay == 1
            app.PLAYButton.Text = 'PAUSE';
        elseif app.isStop == 1
            release(app.fileReader);
            release(app.deviceWriter);
            app.PLAYButton.Text = 'PLAY';
            app.isPlay = 0;
            app.isStop = 0;
        else
            app.PLAYButton.Text = 'PLAY';
        end
    end

    % Button pushed function: RESETButton
    function RESETButtonPushed(app, event)
        % Stop the song if it is currently playing
        if app.isPlay
            app.isStop = 1;
        end

        % Clear stored data
        app.TrackDropDown.Value = {}; % Clear the selected audio file path

        app.audioSignal = [];
        app.sampleRate = [];

        release(app.fileReader);
```

```
            release(app.deviceWriter);

            % Reset sliders and edit fields
            for i = 1:5
                app.(sprintf('Slider_%d', i)).Value = 0;
                app.(sprintf('EditField_%d', i)).Value = num2str(0);

                % Clear both plot and axes
                plot(app.(sprintf('UIAxes%d', i)), NaN, NaN);
                cla(app.(sprintf('UIAxes%d', i)));
            end
        end

    end

    % Component initialization
    methods (Access = private)

        % Create UIFigure and components
        function createComponents(app)

            % Create UIFigure and hide until all components are created
            app.UIFigure = uifigure('Visible', 'off');
            app.UIFigure.Position = [100 100 1204 553];
            app.UIFigure.Name = '5 Band Audio Equaliser';

            % Load background image
            backgroundImage = imread('D:\NUST EME\5th
Semester\Signals_Systems\Lab\Project\Background.jpg');

            % Set the background image
            app.UIFigure.Color = 'none'; % Make the figure background transparent
            app.UIFigure.Position = [100 100 1204 553];

            % Create an axes to display the background image
            app.UIAxesBackground = uiaxes(app.UIFigure, 'Visible', 'off');
            app.UIAxesBackground.PlotBoxAspectRatio = [size(backgroundImage, 2)
size(backgroundImage, 1) 1];
            app.UIAxesBackground.Position = [-100 -180 1500 820];
            imshow(backgroundImage, 'Parent', app.UIAxesBackground);

            % Create UIAxes
            app.UIAxes1 = uiaxes(app.UIFigure);
            title(app.UIAxes1, 'Input Signal')
            xlabel(app.UIAxes1, 'X')
            ylabel(app.UIAxes1, 'Y')
            zlabel(app.UIAxes1, 'Z')
            app.UIAxes1.AmbientLightColor = [0 0 0];
            app.UIAxes1.Box = 'on';
            app.UIAxes1.XGrid = 'on';
            app.UIAxes1.XMinorGrid = 'on';
            app.UIAxes1.YGrid = 'on';
            app.UIAxes1.YMinorGrid = 'on';
            app.UIAxes1.Position = [26 299 300 197];
```

```
            % Create UIAxes2
            app.UIAxes2 = uiaxes(app.UIFigure);
            title(app.UIAxes2, 'Output Signal')
            xlabel(app.UIAxes2, 'X')
            ylabel(app.UIAxes2, 'Y')
            zlabel(app.UIAxes2, 'Z')
            app.UIAxes2.Box = 'on';
            app.UIAxes2.XGrid = 'on';
            app.UIAxes2.XMinorGrid = 'on';
            app.UIAxes2.YGrid = 'on';
            app.UIAxes2.YMinorGrid = 'on';
            app.UIAxes2.Position = [349 299 292 197];

            % Create UIAxes3
            app.UIAxes3 = uiaxes(app.UIFigure);
            title(app.UIAxes3, 'Input Spectrum')
            xlabel(app.UIAxes3, 'X')
            ylabel(app.UIAxes3, 'Y')
            zlabel(app.UIAxes3, 'Z')
            app.UIAxes3.PlotBoxAspectRatio = [2.69491525423729 1 1];
            app.UIAxes3.Box = 'on';
            app.UIAxes3.XGrid = 'on';
            app.UIAxes3.XMinorGrid = 'on';
            app.UIAxes3.YGrid = 'on';
            app.UIAxes3.YMinorGrid = 'on';
            app.UIAxes3.Position = [20 6 313 265];

            % Create UIAxes4
            app.UIAxes4 = uiaxes(app.UIFigure);
            title(app.UIAxes4, 'Output Spectrum')
            xlabel(app.UIAxes4, 'X')
            ylabel(app.UIAxes4, 'Y')
            zlabel(app.UIAxes4, 'Z')
            app.UIAxes4.PlotBoxAspectRatio = [2.69491525423729 1 1];
            app.UIAxes4.Box = 'on';
            app.UIAxes4.XGrid = 'on';
            app.UIAxes4.XMinorGrid = 'on';
            app.UIAxes4.YGrid = 'on';
            app.UIAxes4.YMinorGrid = 'on';
            app.UIAxes4.Position = [359 1 292 276];

            % Create UIAxes5
            app.UIAxes5 = uiaxes(app.UIFigure);
            title(app.UIAxes5, 'Characteristic Frequency')
            xlabel(app.UIAxes5, 'X')
            ylabel(app.UIAxes5, 'Y')
            zlabel(app.UIAxes5, 'Z')
            app.UIAxes5.Box = 'on';
            app.UIAxes5.XGrid = 'on';
            app.UIAxes5.XMinorGrid = 'on';
            app.UIAxes5.YGrid = 'on';
            app.UIAxes5.YMinorGrid = 'on';
            app.UIAxes5.Position = [666 64 365 189];

            % Create Slider_1
```

```
            app.Slider_1 = uislider(app.UIFigure);
            app.Slider_1.Limits = [-12 12];
            app.Slider_1.MajorTicks = [-12 -9 -6 -3 0 3 6 9 12];
            app.Slider_1.MajorTickLabels = {'-12', '-9', '-6', '-3', '0', '3', '6',
'9', '12'};
            app.Slider_1.Orientation = 'vertical';
            app.Slider_1.ValueChangedFcn = createCallbackFcn(app,
@Slider_1ValueChanged, true);
            app.Slider_1.MinorTicks = [-12 -11 -10 -9 -8 -7 -6 -5 -4 -3 -2 -1 0 1 2 3
4 5 6 7 8 9 10 11 12];
            app.Slider_1.Position = [776 358 3 150];
            app.Slider_1.Value = 0;  % Set the default value to 0

            % Create Band1fc63HzLabel
            app.Band1fc63HzLabel = uilabel(app.UIFigure);
            app.Band1fc63HzLabel.HorizontalAlignment = 'center';
            app.Band1fc63HzLabel.Position = [762 279 59 30];
            app.Band1fc63HzLabel.Text = {'Band 1 '; 'fc = 63 Hz'};

            % Create EditField
            app.EditField_1 = uieditfield(app.UIFigure, 'text');
            app.EditField_1.Position = [762 321 55 22];
            app.EditField_1.ValueChangedFcn = createCallbackFcn(app,
@EditField_1ValueChanged, true);
            app.EditField_1.Value = '0';  % Set the default value to '0'

            % Create Band2fc250HzLabel
            app.Band2fc250HzLabel = uilabel(app.UIFigure);
            app.Band2fc250HzLabel.HorizontalAlignment = 'center';
            app.Band2fc250HzLabel.Position = [842 280 66 30];
            app.Band2fc250HzLabel.Text = {'Band 2 '; 'fc = 250 Hz'};

            % Create Slider_2
            app.Slider_2 = uislider(app.UIFigure);
            app.Slider_2.Limits = [-12 12];
            app.Slider_2.MajorTicks = [-12 -9 -6 -3 0 3 6 9 12];
            app.Slider_2.MajorTickLabels = {'-12', '-9', '-6', '-3', '0', '3', '6',
'9', '12'};
            app.Slider_2.Orientation = 'vertical';
            app.Slider_2.ValueChangedFcn = createCallbackFcn(app,
@Slider_2ValueChanged, true);
            app.Slider_2.MinorTicks = [-12 -11 -10 -9 -8 -7 -6 -5 -4 -3 -2 -1 0 1 2 3
4 5 6 7 8 9 10 11 12];
            app.Slider_2.Position = [857 358 3 150];
            app.Slider_2.Value = 0;  % Set the default value to 0

            % Create EditField_2
            app.EditField_2 = uieditfield(app.UIFigure, 'text');
            app.EditField_2.Position = [848 321 55 22];
            app.EditField_2.ValueChangedFcn = createCallbackFcn(app,
@EditField_2ValueChanged, true);
            app.EditField_2.Value = '0';  % Set the default value to '0'

            % Create Band3fc1000HzLabel
            app.Band3fc1000HzLabel = uilabel(app.UIFigure);
```

```
            app.Band3fc1000HzLabel.HorizontalAlignment = 'center';
            app.Band3fc1000HzLabel.Position = [925 280 73 30];
            app.Band3fc1000HzLabel.Text = {'Band 3 '; 'fc = 1000 Hz'};

            % Create Slider_3
            app.Slider_3 = uislider(app.UIFigure);
            app.Slider_3.Limits = [-12 12];
            app.Slider_3.MajorTicks = [-12 -9 -6 -3 0 3 6 9 12];
            app.Slider_3.MajorTickLabels = {'-12', '-9', '-6', '-3', '0', '3', '6',
'9', '12'};
            app.Slider_3.Orientation = 'vertical';
            app.Slider_3.ValueChangedFcn = createCallbackFcn(app,
@Slider_3ValueChanged, true);
            app.Slider_3.MinorTicks = [-12 -11 -10 -9 -8 -7 -6 -5 -4 -3 -2 -1 0 1 2 3
4 5 6 7 8 9 10 11 12];
            app.Slider_3.Position = [941 358 3 150];
            app.Slider_3.Value = 0;  % Set the default value to 0

            % Create EditField_3
            app.EditField_3 = uieditfield(app.UIFigure, 'text');
            app.EditField_3.Position = [932 322 55 22];
            app.EditField_3.ValueChangedFcn = createCallbackFcn(app,
@EditField_3ValueChanged, true);
            app.EditField_3.Value = '0';  % Set the default value to '0'

            % Create Band4fc4000HzLabel
            app.Band4fc4000HzLabel = uilabel(app.UIFigure);
            app.Band4fc4000HzLabel.HorizontalAlignment = 'center';
            app.Band4fc4000HzLabel.Position = [1017 278 69 30];
            app.Band4fc4000HzLabel.Text = {'Band 4 '; 'fc = 4000Hz'};

            % Create Slider_4
            app.Slider_4 = uislider(app.UIFigure);
            app.Slider_4.Limits = [-12 12];
            app.Slider_4.MajorTicks = [-12 -9 -6 -3 0 3 6 9 12];
            app.Slider_4.MajorTickLabels = {'-12', '-9', '-6', '-3', '0', '3', '6',
'9', '12'};
            app.Slider_4.Orientation = 'vertical';
            app.Slider_4.ValueChangedFcn = createCallbackFcn(app,
@Slider_4ValueChanged, true);
            app.Slider_4.MinorTicks = [-12 -11 -10 -9 -8 -7 -6 -5 -4 -3 -2 -1 0 1 2 3
4 5 6 7 8 9 10 11 12];
            app.Slider_4.Position = [1031 359 3 150];
            app.Slider_4.Value = 0;  % Set the default value to 0

            % Create EditField_4
            app.EditField_4 = uieditfield(app.UIFigure, 'text');
            app.EditField_4.Position = [1022 324 55 22];
            app.EditField_4.ValueChangedFcn = createCallbackFcn(app,
@EditField_4ValueChanged, true);
            app.EditField_4.Value = '0';  % Set the default value to '0'

            % Create Band5fc16000HzLabel
            app.Band5fc16000HzLabel = uilabel(app.UIFigure);
            app.Band5fc16000HzLabel.HorizontalAlignment = 'center';
```

```
            app.Band5fc16000HzLabel.Position = [1102 280 79 30];
            app.Band5fc16000HzLabel.Text = {'Band 5 '; 'fc = 16000 Hz'};

            % Create Slider_5
            app.Slider_5 = uislider(app.UIFigure);
            app.Slider_5.Limits = [-12 12];
            app.Slider_5.MajorTicks = [-12 -9 -6 -3 0 3 6 9 12];
            app.Slider_5.MajorTickLabels = {'-12', '-9', '-6', '-3', '0', '3', '6',
'9', '12'};
            app.Slider_5.Orientation = 'vertical';
            app.Slider_5.ValueChangedFcn = createCallbackFcn(app,
@Slider_5ValueChanged, true);
            app.Slider_5.MinorTicks = [-12 -11 -10 -9 -8 -7 -6 -5 -4 -3 -2 -1 0 1 2 3
4 5 6 7 8 9 10 11 12];
            app.Slider_5.Position = [1127 358 3 150];
            app.Slider_5.Value = 0;  % Set the default value to 0

            % Create EditField_5
            app.EditField_5 = uieditfield(app.UIFigure, 'text');
            app.EditField_5.Position = [1114 322 55 22];
            app.EditField_5.ValueChangedFcn = createCallbackFcn(app,
@EditField_5ValueChanged, true);
            app.EditField_5.Value = '0';  % Set the default value to '0'

            % Create LOADButton
            app.LOADButton = uibutton(app.UIFigure, 'push');
            app.LOADButton.ButtonPushedFcn = createCallbackFcn(app,
@LOADButtonPushed, true);
            app.LOADButton.BackgroundColor = [0 0.4471 0.7412];
            app.LOADButton.FontColor = [1 1 1];
            app.LOADButton.Position = [667 10 107 41];
            app.LOADButton.Text = 'LOAD';

            % Create PLAYButton
            app.PLAYButton = uibutton(app.UIFigure, 'push');
            app.PLAYButton.ButtonPushedFcn = createCallbackFcn(app,
@PLAYButtonPushed, true);
            app.PLAYButton.BackgroundColor = [0 0.4471 0.7412];
            app.PLAYButton.FontColor = [1 1 1];
            app.PLAYButton.Position = [787 10 92 41];
            app.PLAYButton.Text = 'PLAY';

            % Create RESETButton
            app.RESETButton = uibutton(app.UIFigure, 'push');
            app.RESETButton.ButtonPushedFcn = createCallbackFcn(app,
@RESETButtonPushed, true);
            app.RESETButton.BackgroundColor = [0 0.4471 0.7412];
            app.RESETButton.FontColor = [1 1 1];
            app.RESETButton.Position = [888 10 107 41];
            app.RESETButton.Text = 'RESET';

            % Create PLOTButton
            app.PLOTButton = uibutton(app.UIFigure, 'push');
            app.PLOTButton.ButtonPushedFcn = createCallbackFcn(app,
@PLOTButtonPushed, true);
```

```
            app.PLOTButton.BackgroundColor = [0 0.4471 0.7412];
            app.PLOTButton.FontColor = [1 1 1];
            app.PLOTButton.Position = [1002 10 107 41];
            app.PLOTButton.Text = 'PLOT';

            % Create SongSelectDropDownLabel
            app.SongSelectDropDownLabel = uilabel(app.UIFigure);
            app.SongSelectDropDownLabel.HorizontalAlignment = 'right';
            app.SongSelectDropDownLabel.Position = [1025 208 70 22];
            app.SongSelectDropDownLabel.Text = 'Song Select';

            % Create SongSelectDropDown
            app.TrackDropDown = uidropdown(app.UIFigure);
            app.TrackDropDown.Position = [1110 206 94 26];

            % Show the figure after all components are created
            app.UIFigure.Visible = 'on';
        end
    end

    % App creation and deletion
    methods (Access = public)

        % Construct app
        function app = Project_GUI_Code
            % Close all existing instances of the app
            existingApps = findall(0, 'Type', 'figure', 'Name', '5 Band Audio 
Equaliser');
            delete(existingApps);

            % Create UIFigure and components
            createComponents(app)

            % Register the app with App Designer
            registerApp(app, app.UIFigure)

            if nargout == 0
                clear app
            end
        end

        % Code that executes before app deletion
        function delete(app)

            % Delete UIFigure when app is deleted
            delete(app.UIFigure)
        end
    end
end
```

Code Explanation:

The code reads an audio file, extracts the audio data, and plots the waveform and spectrum of the audio signal. Here's a breakdown:

1. Loading Audio File:

- The user selects an audio file through a dialog box.
- The code then reads this audio file and extracts the audio data.

2. Plotting Audio Waveform:

- The audio waveform is the graphical representation of how the audio signal varies over time.
- A figure (a window for displaying plots) is created to show the waveform plot.
- The audio signal is plotted on this figure, providing a visual representation of the sound wave.

3. Plotting Audio Spectrum:

- The audio spectrum represents how much of the audio signal exists at different frequencies.
- Another figure is created to display the spectrum plot.
- The Fast Fourier Transform (FFT) is applied to the audio signal to convert it from the time domain to the frequency domain, and the resulting spectrum is plotted.

The code is responsible for creating a graphical user interface (GUI) for controlling a 5-band audio equalizer. The equalizer allows the user to adjust different frequency bands of the audio signal. Let's break it down:

4. Overall GUI Design:

- A GUI figure is created with various components, including sliders, buttons, and dropdowns.
- The figure has background images, axes for plotting signals and spectra, sliders for each frequency band, and buttons for actions like loading, playing, resetting, and plotting.

5. Frequency Bands:

- The equalizer is divided into 5 frequency bands, each centered around a specific frequency.
- For each band, there is a slider to adjust the gain (volume) and an edit field to display and manually set the gain value.

6. Plotting Signals and Spectra:

- The GUI has axes for plotting the input and output audio signals and their respective spectra.

- This helps visualize the effect of equalization on the audio signal.

7. Buttons for Interaction:

- There are buttons for loading an audio file, playing it, resetting the equalizer settings, and plotting the audio signals and spectra.

8. Dropdown for Song Selection:

- A dropdown menu is provided to select different audio tracks for processing.

In-Depth Explanation:

The combined code serves as an interactive tool for both analyzing and modifying audio signals. Users can load different audio tracks, visualize their waveforms and spectra, and interactively adjust the equalizer settings to observe the impact on the audio output. This GUI provides a user-friendly interface for experimenting with audio processing, making it suitable for educational purposes, research, or practical applications in audio engineering.

GUI Interface Images

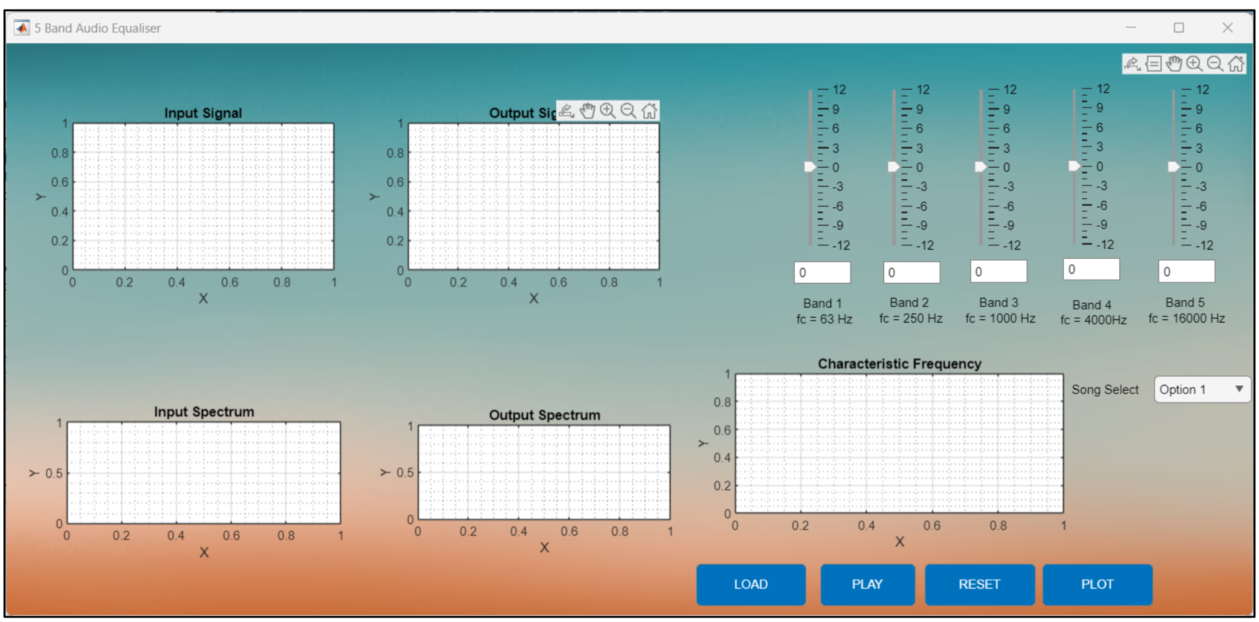


Figure 8: GUI Interface

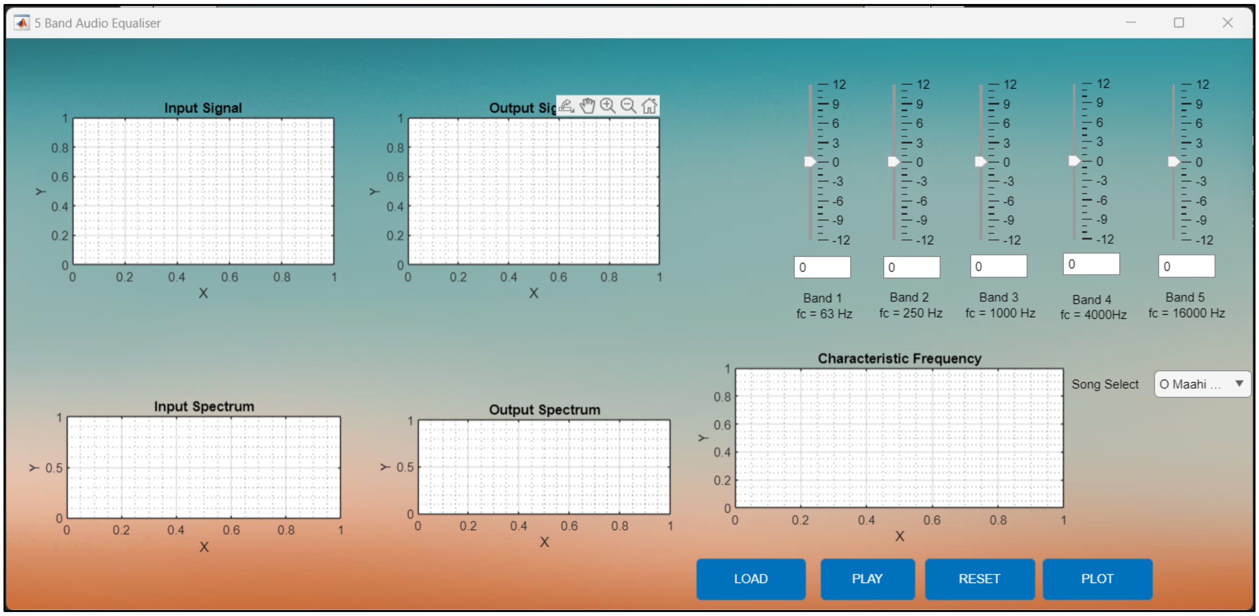


Figure 9: GUI after the Song has been loaded by pressing 'LOAD' button.

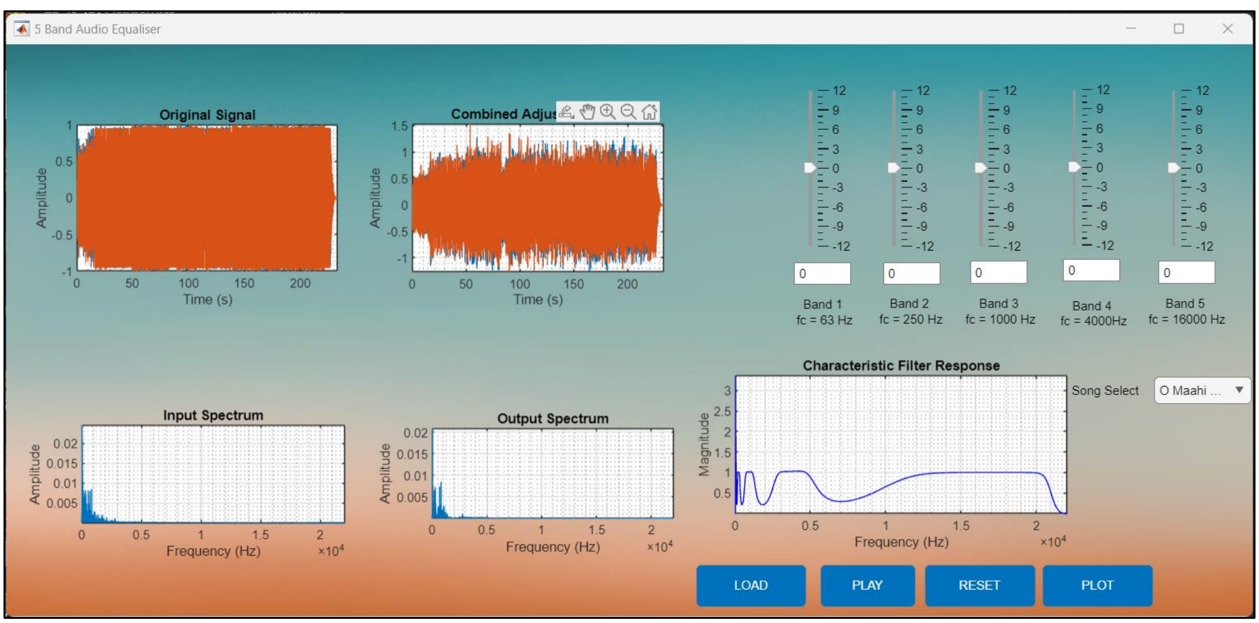


Figure 10: Signal Plotted without any gain

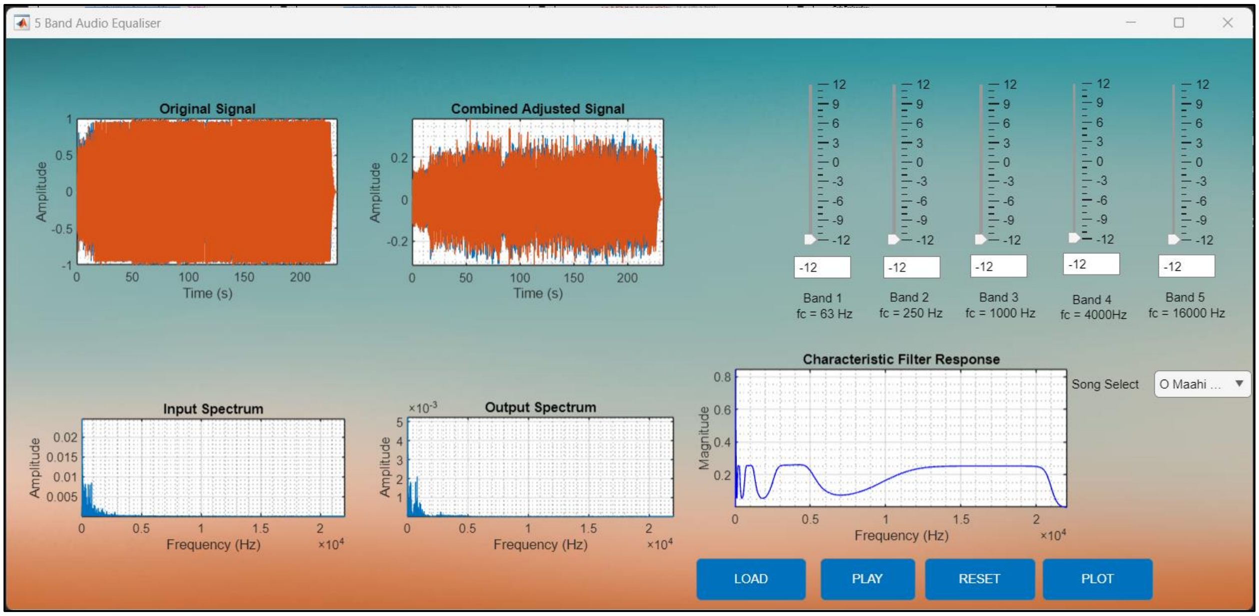


Figure 11: Signal plotted with full negative gain

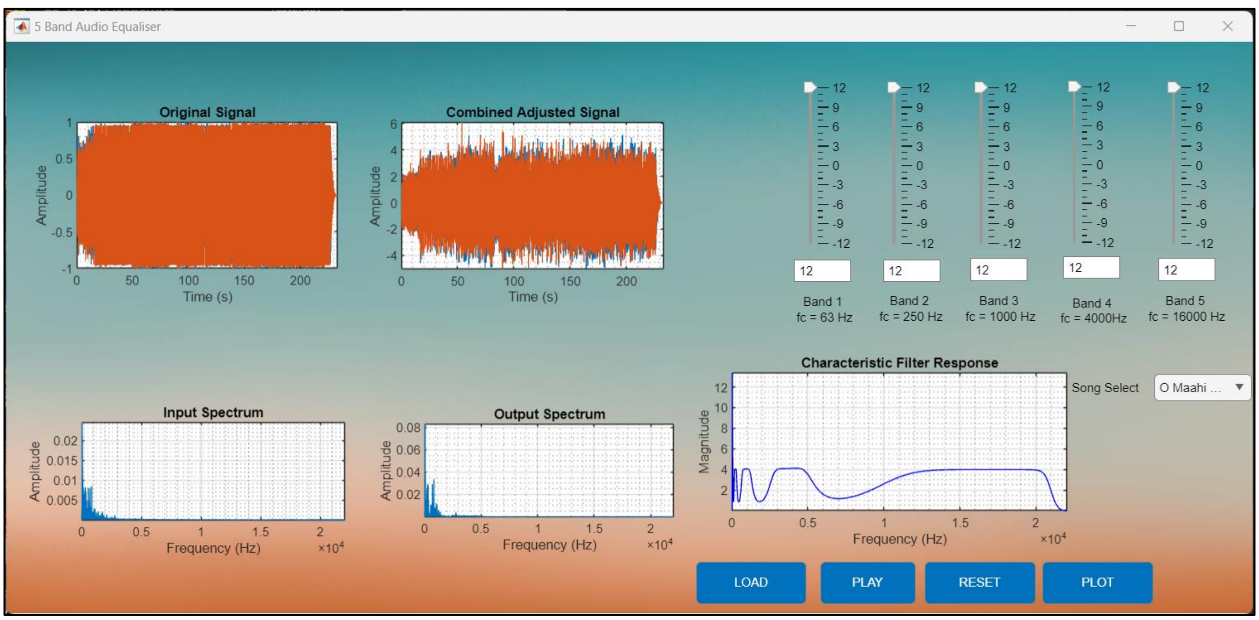


Figure 12: Signal plotted with full positive gain

Conclusion

In summary, this project merged theoretical concepts from our "Signals and Systems" course with practical applications. The first part focused on analyzing audio signals, providing insights into temporal and frequency characteristics. The second part introduced a user-friendly 5-band audio equalizer through a graphical interface, showcasing real-time signal manipulation.

This project bridged theory and practice, emphasizing the application of signal processing techniques like Fourier analysis and equalization. The graphical interface highlighted the importance of user-friendly tools in signal processing. The hands-on experience reinforced MATLAB programming and signal processing skills while deepening our understanding of audio quality's dependence on signal manipulation.

Overall, this project was a valuable exercise, enriching our grasp of signals and systems in the context of audio engineering.

References

1. https://www.diva-portal.org/smash/get/diva2:1334188/FULLTEXT02.pdf
2. https://www.mathworks.com/matlabcentral/fileexchange/23982-digital-audio-equalizer
3. https://www.youtube.com/watch?v=Z7urwX82Z8g
4. https://www.mathworks.com/help/audio/ug/equalization.html
5. https://www.mathworks.com/help/audio/ug/graphic-equalization.html
6. https://www.mathworks.com/help/audio/audio-processing-algorithm-design.html
7. https://github.com/splAcharya/AudioEqualizerMatlab_Simulink
8. https://github.com/MonicaSaid/audio-equalizer
9. https://github.com/mohamedmashaal/Digital-Audio-Equalizer/tree/master