Advanced Filter Design Tool: User Guide & Documentation

1. Introduction

The Advanced Filter Design tool provides a user-friendly interface for designing and analyzing various types of filters. These include Butterworth, Chebyshev, Elliptic, and Legendre filters.

2. Tool Usage

2.1 Launching the Tool

To launch the tool, simply run the `mainFilterDesignGUI()` function in MATLAB.

2.2 Selecting Filter Type

- Use the dropdown menu to select your desired filter type.
- The plotted signals will update automatically upon changing the filter type.

2.3 Saving the Filtered Signal

- Click on the "Save Signal" button to save the current filtered signal.
- Choose your desired save location and provide a filename with a `.mat` extension.

2.4 Viewing Filter Information

- Click on the "Filter Info" button to view the filter's coefficients and other properties.

3. Mathematical Foundations

3.1 Filter Types

1. **Butterworth Filter**:

- Defined as having a frequency response as flat as possible in the passband.
- Mathematical Formula:

$$|H(j\omega)|^2 = \frac{1}{1 + (\frac{\omega}{\omega_c})^{2n}}$$

where n is the order of the filter, and ω_c is the cutoff frequency.

2. **Chebyshev Filter**:

- Allows for ripples in the passband, which makes it sharper than the Butterworth filter.
- Mathematical Formula for Type I:

$$|H(j\omega)|^2 = \frac{1}{1 + \epsilon^2 C_n^2(\frac{\omega}{\omega_c})}$$

where C_n is the nth-order Chebyshev polynomial and ϵ dictates the ripple amount.

3. **Elliptic Filter (or Cauer Filter)**:

- Features ripples in both the passband and the stopband. It offers the steepest transition between the passband and the stopband for a given filter order.
- Mathematical Formula: (is more involved due to the ripple in both passband and stopband). It uses elliptic functions for its computation.

4. **Legendre Filter**:

- It uses Legendre polynomials to give the steepest slope near the cut-off frequency without any ripple in the passband.
- The Legendre polynomial $P_n(x)$ of degree n is defined recursively.

3.2 Filter Design Parameters

1. **Pass Band Frequency (f_p)**: This is the frequency below which the filter response is above the desired gain level.
2. **Stop Band Frequency (f_s)**: This is the frequency after which the filter response is below the acceptable gain level.
3. **Pass Band Attenuation (r_p)**: This denotes the maximum permissible ripple in the passband.
4. **Stop Band Attenuation (r_s)**: It gives the minimum required attenuation in the stopband.
5. **Sampling Frequency (f_2)**: This is the frequency at which the analog signal is sampled.

4. Conclusion

This GUI-based tool allows for the rapid design, analysis, and comparison of various filter types. It abstracts the complex mathematical intricacies behind each filter type, making it suitable for both beginners and experts in the field of signal processing.
