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Course Project Assignment Report

on

Simulation of FIR Low Pass Filter and High Pass Filter with Sawtooth Input using Falstad.com Digital Filter Simulator

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1. Introduction

Digital filters are essential in applications like audio processing, communications, and instrumentation, where specific frequency components must be extracted or removed. Finite Impulse Response (FIR) filters are particularly preferred due to their stability and linear phase characteristics.

In this project, **FIR Low Pass** and **High Pass Filters** are simulated using the Falstad.com Digital Filter Simulator by applying a **sawtooth input signal.** Since a sawtooth wave contains a strong combination of fundamental and harmonic frequencies, it is ideal for studying how filters respond to multi-frequency signals.

2. Objective

- To design and simulate an FIR Low Pass Filter (LPF) and an FIR High Pass Filter (HPF).
- To apply a **sawtooth waveform** as the input signal.
- To observe how each filter behaves when processing a multi-frequency harmonic-rich input.
- To visualize the time-domain and frequency-domain characteristics using the Falstad simulator.

3. Tools Used

- **Falstad Digital Filter Simulation Tool** (browser-based)
    - Provides real-time signal visualization
    - Allows user-defined filter coefficients
    - Supports noise generation and waveform analysis

4. Methodology

4.1 FIR Low Pass Filter Simulation

1. Open the Falstad Digital Filter Simulator and select the FIR filter module.
2. Enter FIR low-pass coefficients (using equal weights or window-based design).
3. Select *Sawtooth Wave* as the input signal.
4. Observe the response of the LPF and note the following:
    a. The lower-frequency components of the sawtooth wave are retained.
    b. Higher-order harmonics (which give the sawtooth its sharp edges) are suppressed.

c. The output waveform becomes smoother, resembling a sine-like signal as higher harmonics are removed.

4.2 FIR High Pass Filter Simulation

1. Configure the FIR filter with high-pass coefficients (differentiator-like or window-based HPF coefficients).
2. Apply the same noisy input signal.
3. Observe:
   - High-frequency components are retained.
   - Low-frequency portions of the input signal are suppressed.
   - Noise (mostly high-frequency) may still appear, depending on cutoff.

5. Observations

- The FIR Low Pass Filter removed the higher harmonics of the sawtooth wave, resulting in a smoother signal with reduced sharpness.
- The FIR High Pass Filter suppressed the fundamental component and amplified the sharper high-frequency harmonics of the sawtooth waveform.
- Falstad's graphical interface clearly exhibited the difference between the original sawtooth wave and the filtered outputs through:

- Waveform plots
- Frequency spectrum
- Impulse response visualization

6. Results

- The FIR LPF produced a rounded output waveform by retaining only the low-frequency part of the sawtooth wave.
- The FIR HPF enhanced the harmonic components, generating a waveform primarily containing high-frequency elements.
- The simulation results matched theoretical expectations for both FIR LPF and HPF when applied to a harmonic-rich sawtooth input.

7. Conclusion

This project successfully demonstrates the simulation of FIR Low Pass and High Pass Filters using a sawtooth wave in the Falstad.com Digital Filter Simulator.
The sawtooth signal, containing multiple harmonics, clearly highlighted the filtering characteristics of both LPF and HPF.

The LPF smoothed the waveform by removing higher harmonics, whereas the HPF emphasized higher-order components, validating FIR filter behavior in practical signal processing scenarios

8. Future Scope

- Design FIR filters using advanced window methods such as Hamming, Kaiser, and Blackman.
- Compare time and frequency responses of FIR and IIR filters for sawtooth input.
- Implement the same filter designs in MATLAB, Python, or Scilab The project can be expanded by integrating FIR filters into practical DSP applications such as audio equalizers, communication receivers, or embedded DSP boards to analyze real-time filtering performance. for deeper analysis.
- Extend the study using other harmonic-rich signals like square waves for comparative understanding.