**Experiment 3: Filters Experiment Report**

**Title**: Experimental Study on Filtering of High Frequency Noise

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**I. Introduction**

The aim of this experiment is to demonstrate techniques for filtering a noisy electrical signal. A noisy signal is generated by adding a high-frequency signal to a “clean” signal using a summing amplifier. Hardware filtering of the noisy signal is tested using first and second-order active filters, and software filtering is achieved by capturing the signal to obtain raw data and using software tools. It is crucial to include all circuit diagrams in the report as they are essential for understanding the experimental setup and the functioning of the filters. Signal filtering is of great significance in electronic circuits as it enables the extraction of useful information from noisy signals, enhancing the overall performance and reliability of the system.

**II. Experimental Procedures and Results**

**Part 1: Hardware Filtering of Noise**

1. **Signal Generation**
   * To generate a high-frequency signal to approximate noise, the function generator was set to produce a sine wave with a frequency of 5 kHz and 500 mVpp. A clean signal was generated by setting the second function generator to produce a sine wave signal of 1 kHz and 2 Vpp.
   * The noise was added to the clean signal using a summing amplifier designed in the standard inverting operational amplifier configuration. To re-invert the inverted output voltage, a single-input inverting adder with a gain of one was added to the circuit.
2. **Circuit Testing and Graphical Representation**
   * Representative graphs were produced for the clean signal, the noise signal, and the noisy signal. These graphs provide a visual understanding of the signals before and after the addition of noise.

**Part 2: First-Order Filter**

1. **Filter Design and Implementation**
   * An appropriate cut-off frequency of 1200 Hz was chosen for the first-order filter, which is slightly higher than the frequency of the clean signal. The passive component values were determined based on the filter design requirements. The first-order active filter was then designed, implemented, and tested.
2. **Data for Report**
   * Graphs were generated to show the input signal and the noisy signal, as well as the noisy signal and the output from the first-order filter. The frequency response of the first-order filter was analyzed, and it was observed how it attenuated frequencies above the cut-off frequency.

**Part 3: Second-Order Filter**

1. **Filter Design and Implementation**
   * The same cut-off frequency of 1200 Hz was used for the second-order filter. The FilterLab® V2.0 software was used to design the second-order filter. The passive component values were determined using the coefficient method, and the circuit was implemented and tested.
2. **Data for Report**
   * Graphs were produced to show the noisy signal and the output from the second-order filter, as well as the comparison between the outputs of the first and second-order filters. The frequency response of the second-order filter was studied, and it was noted that it had a steeper roll-off compared to the first-order filter, providing better attenuation of frequencies outside the passband.

**Part 4: Digital Oscilloscope Measurements**

1. **Signal Display and Analysis**
   * Using a digital oscilloscope, the two input signals (clean and noise), the input signal and noisy signal, the noisy signal and output from the first-order filter, and the comparison between the outputs of the first and second-order filters were all shown.
   * Comments on the results indicated that the filters effectively reduced the noise in the signal, with the second-order filter showing better performance in terms of noise attenuation.

**Part 5: Filtering using NI LabVIEW**

1. **LabVIEW Setup and Filtering**
   * The noisy circuit was connected to LabVIEW using an NI DAQ. A LabVIEW VI was constructed to perform first and second-order filtering of the undesired frequencies from the signal using the Filter Express VI.

**III. Additional Work**

1. **Cut-off Frequency Selection**
   * The cut-off frequency of 1200 Hz was chosen to be slightly higher than the frequency of the clean signal (1 kHz) to effectively filter out the added high-frequency noise while minimizing the attenuation of the desired signal.
2. **Bode Plot Generation in Multisim Live**
   * Bode plots were produced for the first and second-order filters in Multisim Live. These plots provided a detailed frequency response analysis, showing the gain and phase characteristics of the filters as a function of frequency.
3. **Chebyshev Filter Design and Bode Plot**
   * Using FilterLab 2, a second-order Chebyshev Filter with the same cut-off frequency as the Butterworth Filter was designed. The Bode plot for this filter was generated in Multisim Live, and the frequency response was compared to that of the Butterworth filter.
4. **Filter Comparison**
   * The Butterworth filter has a maximally flat frequency response in the passband, while the Chebyshev filter has a steeper roll-off but with some ripple in the passband. The choice between the two filters depends on the specific requirements of the application. If a flat response in the passband is crucial, the Butterworth filter may be preferred. However, if a faster roll-off is needed, the Chebyshev filter could be a better choice, despite the presence of some ripple.

**IV. Conclusion**

This experiment successfully demonstrated the techniques for filtering a noisy electrical signal using both hardware and software methods. The first and second-order active filters were designed, implemented, and tested, and their performance was analyzed through various graphical representations and measurements. The additional work on filter analysis and comparison provided a deeper understanding of the characteristics and applications of different types of filters. The knowledge and skills gained from this experiment are valuable for future studies and applications in the field of signal processing and electronics, where noise filtering is a critical aspect for accurate signal analysis and system performance.