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Electrical & Electronic Principles

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1 Introduction

A low pass filter allows the passing of low frequency signals while it weakens the higher frequencies. They are used in audio processing to filter unwanted noises. High pass filters are the opposite of low pass filters and are used in audio processing to emphasise treble. In this report an experiment will be carried out to measure the input and output voltages of the circuits at different frequencies. This will then be used to find data such as the attenuation, cut off frequency, and frequency response of the circuits which will be compared to one another to see how the circuits behave under the same variables.

2 Literature review

2.1 Low pass filter

A low-pass filter is a circuit that attenuates signals over a given cutoff frequency while permitting signals below that cutoff to flow through with ease (Sujatha *et al.*, 2022). The cut off frequency establishes the line separating high and low frequencies. This frequency allows signals below to pass through, while signals above are attenuated (Sujatha *et al.*, 2022). Low-pass filters are used by subwoofers to block high frequencies that they are unable to reproduce well.

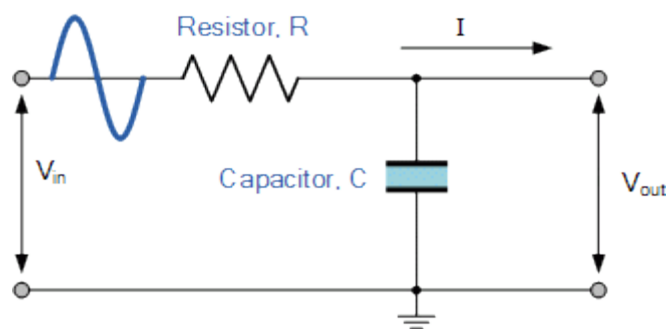


Figure 1: Image showing low pass circuit.

The image above shows a low pass circuit and from the image we can see that the voltage (V_{out}) is measured across the capacitor.

2.2 High pass filter

This is a circuit that attenuates low-frequency signals while passing high-frequency ones. This is the reverse of a low-pass filter, which allows low sounds to be blocked while allowing

high pitches to pass. High-pass filters are used by tweeters in speakers to concentrate on treble sounds (Kumar Singh, Kumar Tiwary and Gupta, 2017).

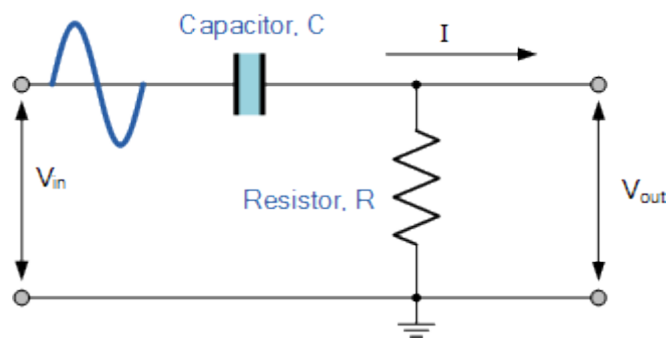


Figure2: Image showing high pass circuit.

The image above shows a high pass circuit and from the image we can see that the voltage (V_{out}) is measured across the resistor.

3 Experimental procedure

Materials:

- Breadboard
- Contact leads with crocodile clips.
- Wire jumpers
- Function generator
- Oscilloscope
- 10k Ω resistor
- 560pF capacitor
- 15nF capacitor

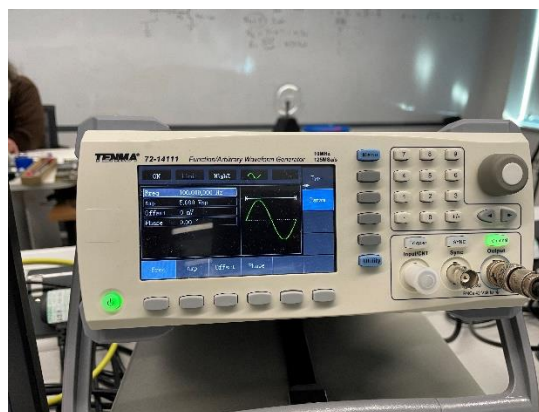


Figure 2: image of a function generator.

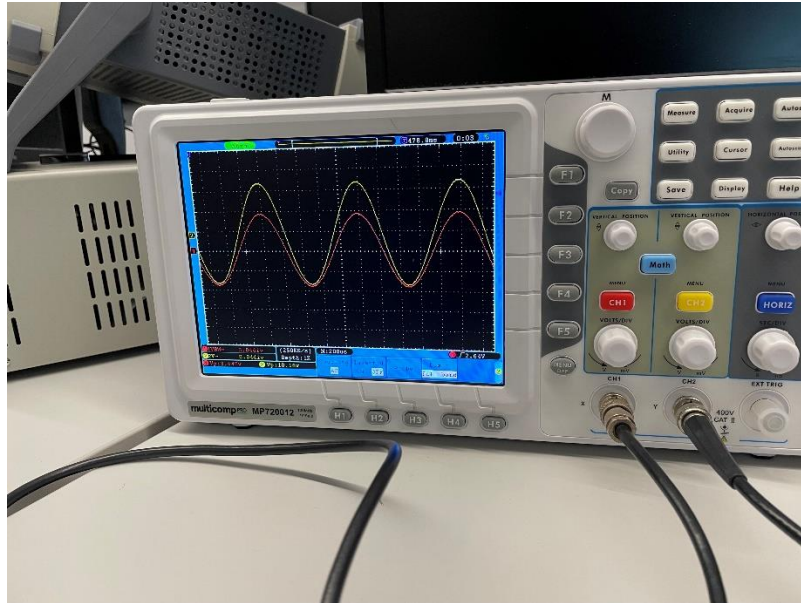


Figure 2: image showing oscilloscope.

Procedure

1. Set up the low pass filter circuit and use the contact leads and the jumper wires to connect the function generator and the oscilloscope. Set the function generator peak to peak voltage to 5 volts (this will be used throughout the experiment). Set the frequency to 100 hertz (Hz) and measure the output voltage (V_{out}) and the input voltage (V_{in}).
2. Control the frequency gradually on the function generator between the frequency range of 100Hz to 300kHz. At each frequency measure and note down the V_{out} and V_{in} into a spreadsheet application.
3. Set up the high pass filter circuit and connect it to the function generator and the oscilloscope as done for the low pass filter circuit. When measuring the V_{out} and V_{in} for the high pass filter circuit it is best to start with a frequency vice versa to the one used for the low pass filter circuit e.g.(4kHz – 100Hz).
4. After noting down the V_{out} and the V_{in} of the two circuits, use a spreadsheet application to calculate the attenuation of the two circuits using the following equation: $A = 20 \times \log_{10} V_{out}/V_{in}$.

5. Use the spreadsheet application to plot graphs for the attenuation against frequency (plotted on the x axis) for both the low pass and high pass filter circuits.

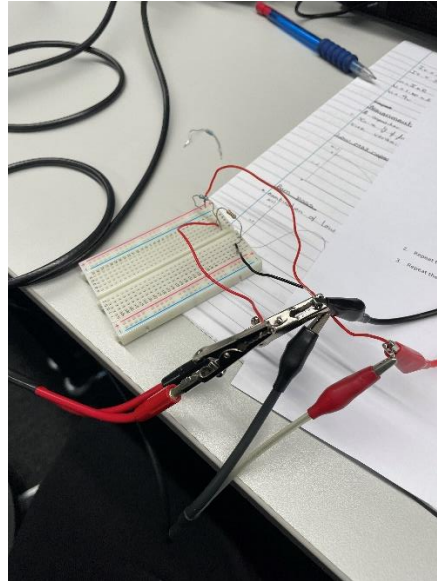


Figure 3: image showing experiment setup.

4 Results

4.1 Theoretical Results

Low pass filter

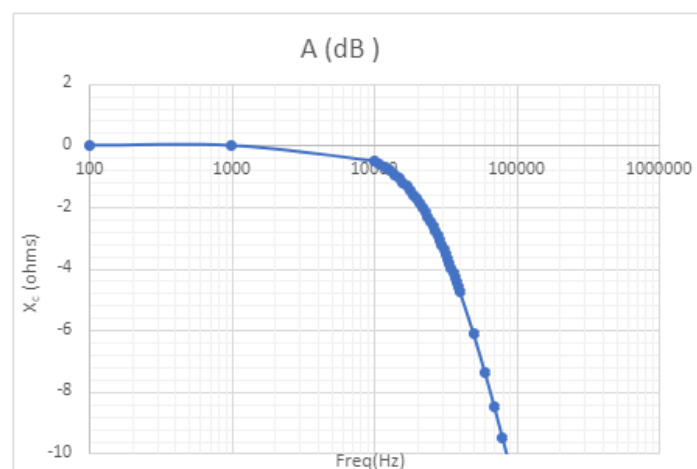


Figure 4: image showing Attenuation graph in decibels.

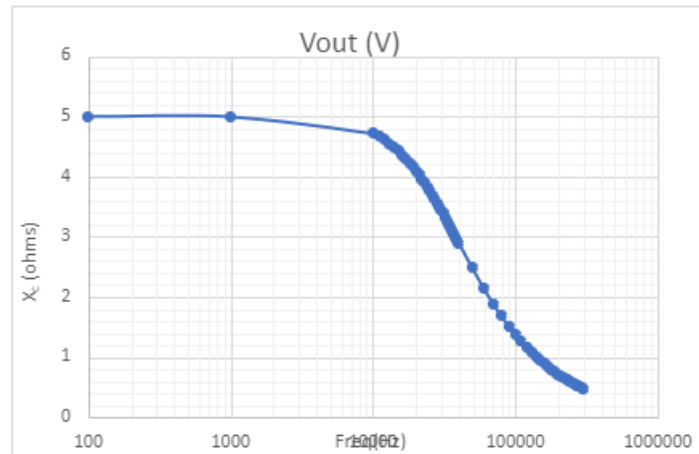


Figure 5: image showing V_{out} graph in volts.

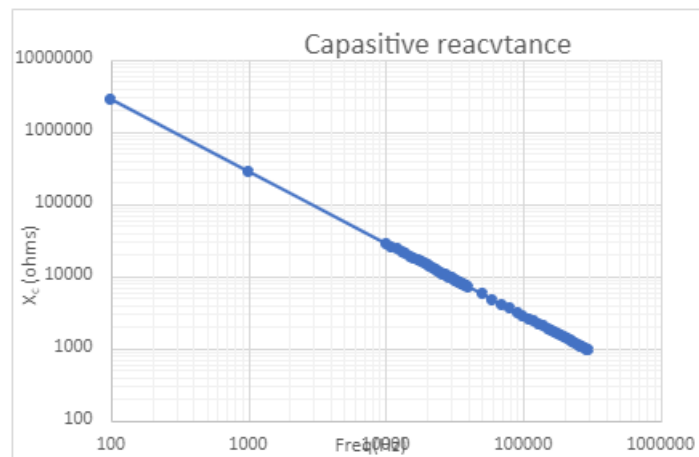


Figure 6: image showing capacitive reactance graph in ohms.

High pass filter

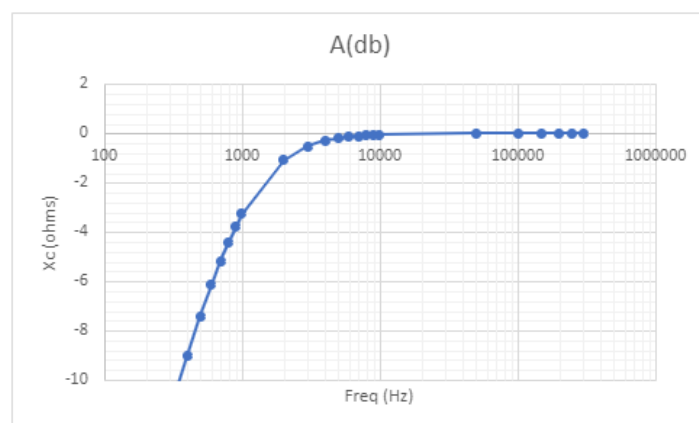


Figure 7: image showing Attenuation graph in decibels.

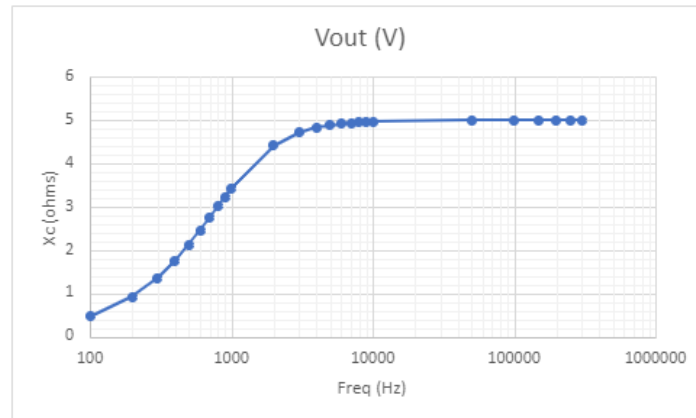


Figure 8: image showing V_{out} graph in volts.

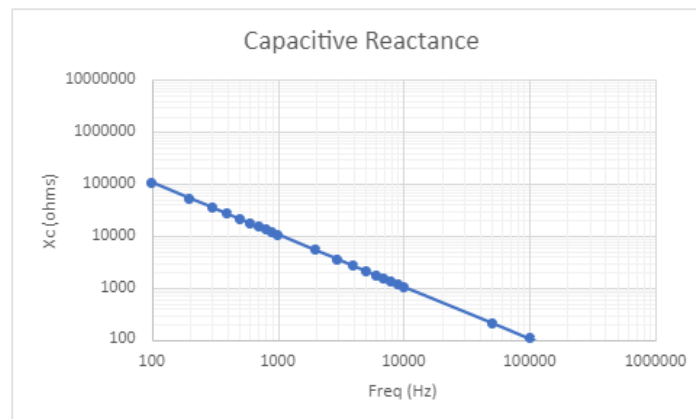


Figure 9: image showing capacitive reactance graph in ohms.

4.2 Experimental results

Low pass filter

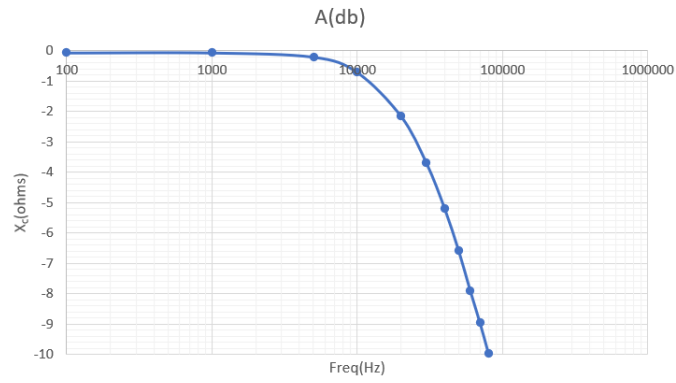


Figure 10: image showing Attenuation graph in decibels.

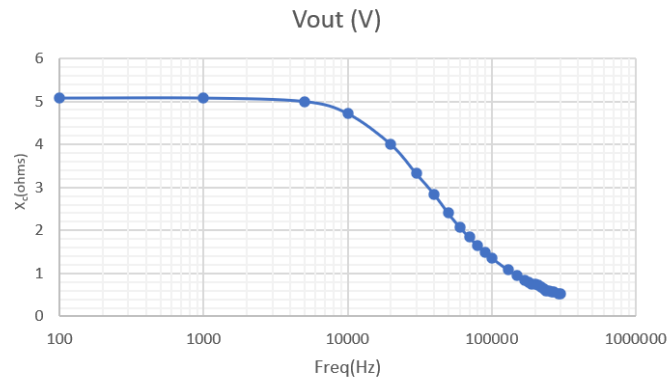


Figure 11: image showing V_{out} graph in volts.

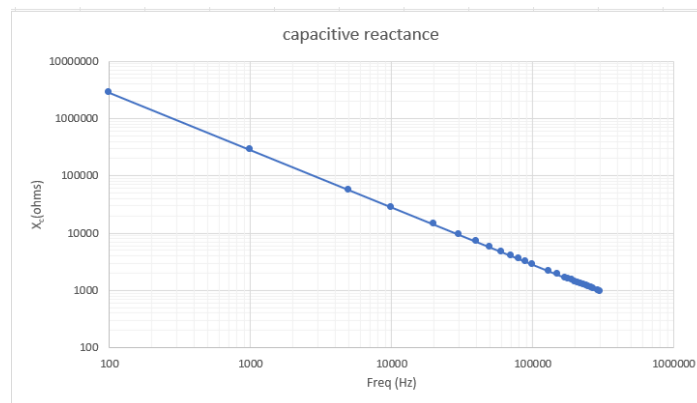


Figure 12: image showing capacitive reactance graph in ohms.

High pass filter

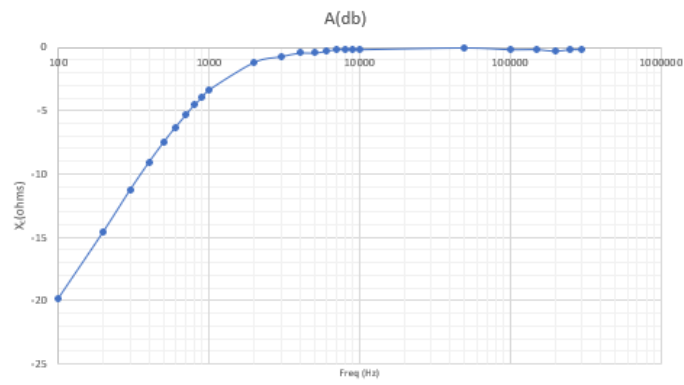


Figure 13: image showing Attenuation graph in decibels.

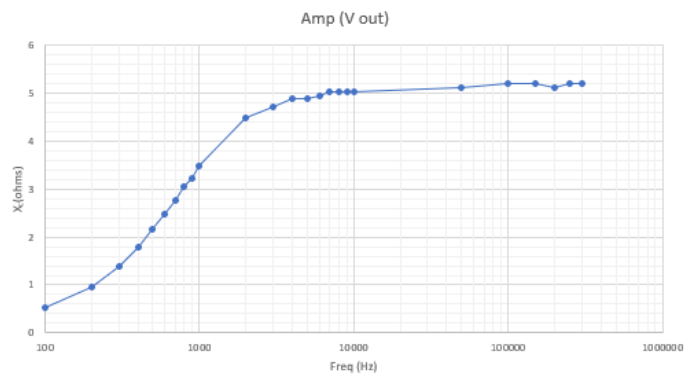


Figure 14: image showing V_{out} graph in volts.

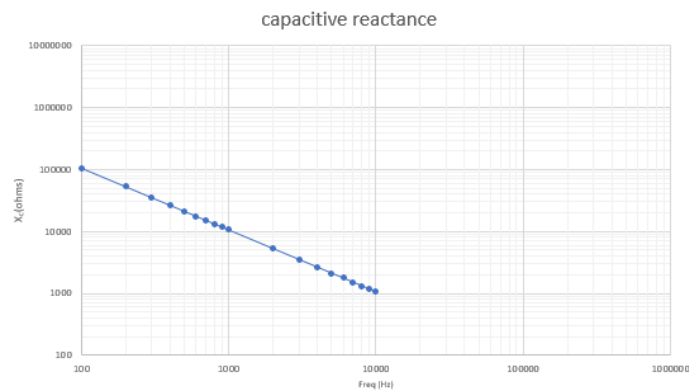


Figure 15: image showing capacitive reactance graph in ohms.

5 Analysis

From the results we see that the attenuation of the low pass filter remains near 0 decibels meaning that the signal passes through with minimal reduction. The flat line between the 100 and 1000 Hz represent the filters passband. Around the cutoff frequency we see the attenuation rise gradually which indicates decrease in signal strength. This region of the graph marks the transition from the passband to the stopband (Liu *et al.*, 2023). After the cutoff frequency, the attenuation sharply rises at a constant rate, reducing the strength of the signal. This is the stopband region where unwanted high frequencies are blocked by the filter. The shape of the experimental graph differs slightly from the theoretical graph as the slope of the theoretical is at -20dB/decade (Wang *et al.*, 2021). This is due to several factors such as the function generator. The function generator does not output a constant 5 Volts which affects the calculation of the attenuation. The resistor also affects the attenuation as the capacitor is not exactly 100Ω. The colour band on the resistor used is a gold band which means that the resistor is $\pm 5\%$ of 100Ω (Wang *et al.*, 2021). This is why the theoretical and experimental graphs are different.

The V_{out} graph for the low pass filter starts off relatively flat at lower frequencies which allow them to pass through without being changed. It then starts to gradually slope down as the frequencies increase (attenuating the higher frequencies) (Liu *et al.*, 2023). The voltage eventually reaches 0.52 at 300000Hz. Comparing the theoretical and the experimental graphs we see the voltages at 300000Hz are different as the theoretical is 0.42volts where the experimental is 0.52volts. This is due to the same factors as mentioned earlier such as the resistor being $\pm 5\%$ of 100Ω and the function generator does not provide a constant 5volts as compared to the fixed values for the theoretical.

The downward slope of the capacitive reactance (X_c) graph caused by the way the capacitors impedance changes with frequency. Capacitive reactance is inversely proportional to frequency, $X_c = 1/(2\pi fC)$, where C is the capacitance (Khan *et al.*,). X_c is quite high at lower frequencies, as the capacitor will be blocking most of the current flow in the circuit. As frequency increases, X_c decreases which allows more flow of current. At the cut off frequency X_c equals the resistance of the resistor in the circuit. After the cutoff point X_c continues to decrease as frequency increases meaning the capacitor allows increasingly current as frequency increases.

The attenuation graph for the high pass filter is the opposite of the low pass filter attenuation graph. At low frequencies is where most of the attenuation is experienced as the unwanted low frequency components are blocked. The higher frequencies are when we see the reduction in the attenuation until there is no or very little attenuation as the filter allows all higher frequency components to pass through unchanged. The shape of the theoretical and experimental graph for attenuation differ as there are factors that affect the results of the filter such as the resistor being $\pm 5\%$ of the 100Ω value (Khan *et al.*,).

The high pass V_{out} graph for the high pass filter starts off gradually sloping up as the frequencies increase. This is because at low frequencies the filter blocks the unwanted components whereas at higher frequencies it allows them to pass. As the frequencies get higher the graph tends to become relatively flat. Comparing the theoretical to the experimental graphs we can see that the theoretical graph maintains a flat graphical line at higher frequencies, whereas the graphical line for the experimental graph is quite bumpy. This is due to factors such as the capacitor and resistor values not being accurate to what they are valued at. This can also be due to the function generator not producing exactly 5 volts.

The high pass filter capacitive reactance (X_c) graph has a decreasing reactance as frequency increases. At low frequencies, the denominator of the formula $X_c = 1/(2\pi fc)$ becomes quite large making the X_c value become high (Sehra *et al.*,). A high X_c value means the capacitor opposes changes in voltage. This causes the capacitor to block signal which does not allow it to pass through the filter. At high frequencies, the reactance decreases meaning that opposition to voltage becomes less. This results in a great amount of signal passing through the filter with minimal attenuation.

6 conclusion

In this experiment, it has been determined that in signal processing, low-pass and high-pass filters are essential instruments for adjusting a signal's frequency content. They work by partially blocking certain frequencies, while only slightly attenuating others. For the low pass filter, we see that it reduces the attenuation of high-frequency frequencies while attenuating low-frequency signals. The output signal amplitude in the graphs above illustrates this, staying high at low frequencies and progressively dropping as the frequency rises. For the

high pass filter, we see that it minimizes the attenuation of low-frequency sounds while attenuating high-frequency frequencies. The output signal amplitude of a high-pass filter is depicted in the above graphs as being low at low frequencies and increasing with frequency.

7 References

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Kumar Singh, P., Kumar Tiwary, A. and Gupta, N. (2017) 'Ultra-compact switchable microstrip band-pass filter–low-pass filter with improved characteristics', *Microwave and Optical Technology Letters*, 59(1), pp. 197-201 Available at: <https://doi.org/10.1002/mop.30262>.

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