

University of Wales Trinity Saint David
School of Engineering

Passive RC Filter Networks
- Technical Report
Electrical & Electronic Principles
ACDB4002

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1 Abstract

During this experiment, tests were carried out with breadboards to collect and analyse an array of results. During the past weeks instructions were given to connect several components on a breadboard to a power supply unit and a function generator to obtain and measure input voltage, output voltage and attenuation. Once results had been obtained, they would be summarised into a table then graphed on excel. This report will explain each of the experiments along with their results to aid the reader in further understanding the workings of high/low pass filter RC circuits.

2 Introduction

In this experiment two circuits were used, a low pass filter circuit and a high pass filter circuit. Both circuits had different layouts/components which gave varying results to one another, the goal was to gather an array of results through conducting a series of tests on the circuits.

A low pass filter, by its definition, allows low frequency signals to be passed through easily whilst making it difficult for high-frequency signals (All about circuits, 2019). The use of low pass filters is abundant in the electrical industry due to their capability to remove unwanted high frequency signals from systems, this flexibility allows the user to design their circuit to only accept certain frequencies.

The blocking of the frequencies is called “attenuating” which is a value given by the formula “ $=20 \cdot \text{LOG}_{10}(v_{\text{out}}/v_{\text{in}})$ ”, this value is incredibly small at low frequencies on a low pass filter, whilst it is higher at higher frequencies. Another value measured on an RC filter circuit is Capacitive Reactance, defined as “the reactance of a capacitor varies inversely with frequency, while the value of the resistor remains constant as the frequency changes.” (electronics tutorials, 2018). The cut-off frequency of a low pass filter is -3dB. Capacitive Reactance is also inversely proportional to the attenuation meaning at low frequencies, the value of will be very high. The result of these values will indicate a far lower voltage drop in comparison to the voltage potential, however “At high frequencies the reverse is true with V_C being small and V_R being large due to the change in the capacitive reactance value.” (electronics tutorials, 2018).

The low pass filter is commonly found in the audio industry, due to its ability to exclude high frequencies which may interfere with the result of the recording.

A high pass filter is like a low pass filter, however; it blocks lower frequencies as opposed to high frequencies. When obtaining results from a high pass filter, it is common practice to begin taking readings from the highest frequency to the lowest frequency (300,000 Hz to 1Hz in the experiment carried out for this report) because the value of attenuation will be invariably small in comparison to the values lower down the frequency table. As the high pass filter works inversely to the low pass filter, it is correct to assume the Capacitive Reactance will increase as the frequency decreases. The result of these factors will indicate a voltage drop in line with the reduction of the output frequency.

High pass filters are also used in electronics, a common use can be defined as “Using a stereo system as a practical example, a capacitor connected in series with the tweeter (treble) speaker will serve as a high-pass filter, imposing a high impedance to low-frequency bass signals, thereby preventing that power from being wasted on a speaker inefficient for reproducing such sounds.” (all about circuits 2019).

In the rest of this report the experiments will be explained in detail, along with their results. The reader will be made aware of different parameters used during the experiment accompanied by circuit diagrams and graphs. Once the results have been explained, they will then be compared with each other (experimental and theoretical results).

3 Circuit Descriptions

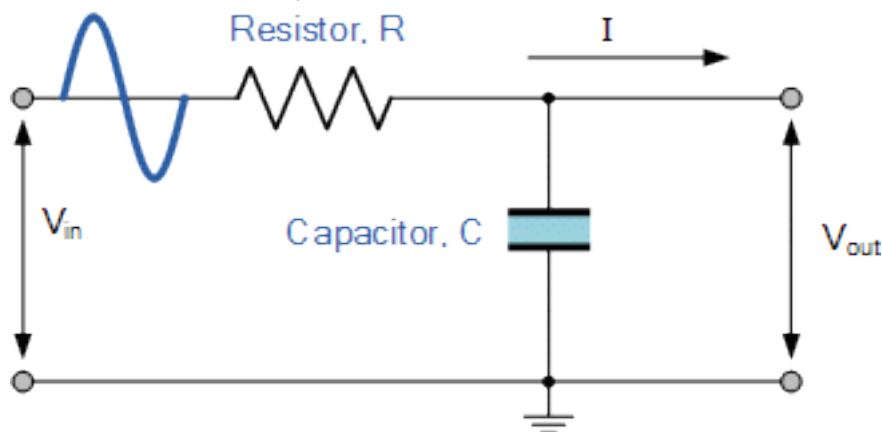


Figure 1: Low Pass Filter RC Circuit Diagram (electronics tutorials, 2018b)

During this experiment the circuits were set up to obtain results with a goal to determine different values at the -3dB cut-off point. Firstly, a function generator will be connected to a low pass filter RC circuit (Figure 1) with the output set to 5Vpk-pk, this voltage will pass through the circuit and readings will be taken from either side of the capacitor. Wires either side of the capacitor will be connected to crocodile cables, which will be connected to the output reader.

Once the circuit is set up correctly, the user would change the frequencies from 100hz to 300khz in varying increments to obtain a series of V_{out} (output voltage) values which will be plotted in to excel and graphed against Frequency and V_{in} (input voltage). Several closely spaced measurements will need to be taken around the peak response to determine the peak and the half amplitude points correctly. The input voltage will remain relatively constant, the only variable factor will be the tolerances of the components, they will be discussed further on in this report. Once a comprehensive set of results has been taken, the attenuation will be calculated using the equation presented in the introduction of this report then graphed against the frequency.

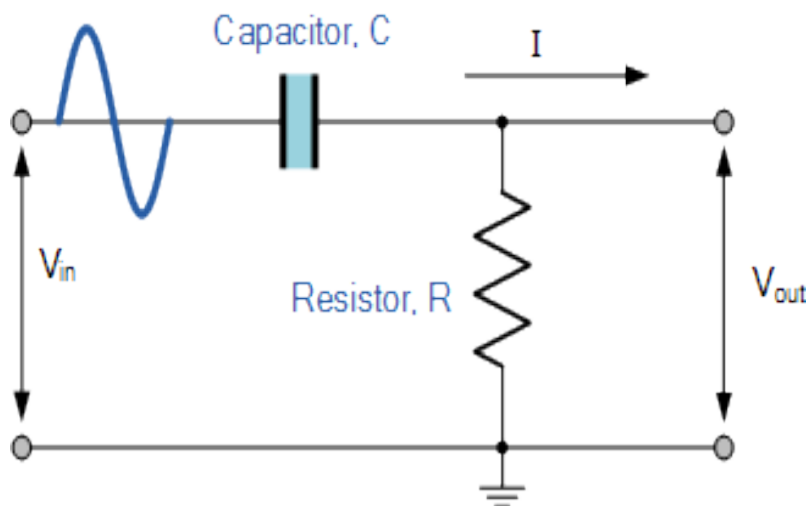


Figure 2: High Pass Filter RC Circuit Diagram (electronics tutorials, 2019)

Following the first experiment of obtaining results from the low pass RC filter circuit, the same would be carried out on a high pass RC filter circuit (Figure 2). The circuit would be set up as per the diagram, then connected to a function generator and reading device via crocodile cables, the function generator would then be set to 5Vpk-pk as was done on the low filter RC filter circuit. In contrast to the prior experiment, the frequency would be set at 300kHz, dropping to 1Hz with varying increments to ensure accuracy of results taken around the peak of the response and the half amplitude points.

Much like the first experiment, the V_{in} is expected to remain at a constant value with very little variance, however variance can be present due to tolerances within the components. At the higher end of the frequency scale, the values of the v_{out} are expected to be similar to the v_{in} values, with very small voltage drops as the frequency decreases. However, once the frequency begins to drop below a certain value, the reduction in voltage drop is expected to increase due to the nature of the high pass filter, this is where smaller incremental frequency decreases will be vital to obtaining accurate results. As attenuation is the blocking of signals, the attenuation is expecting to increase as the v_{out} decreases.

4 Results

A variance of results were obtained through different methods to produce comparable data alongside theoretical results created through pre-set value and general equations. During this part of the report, we will present both theoretical and actual results obtained during this phase of coursework, the graphs of each will be laid out and explained along with any noticeable differences. The explanations of the results will be explained to greater detail in the discussion phase of this report along with background knowledge on the tolerances of certain components (which may be responsible for slight inconsistencies and variations within results).

4.1 Low Pass Filter RC Circuit Theoretical Graphs

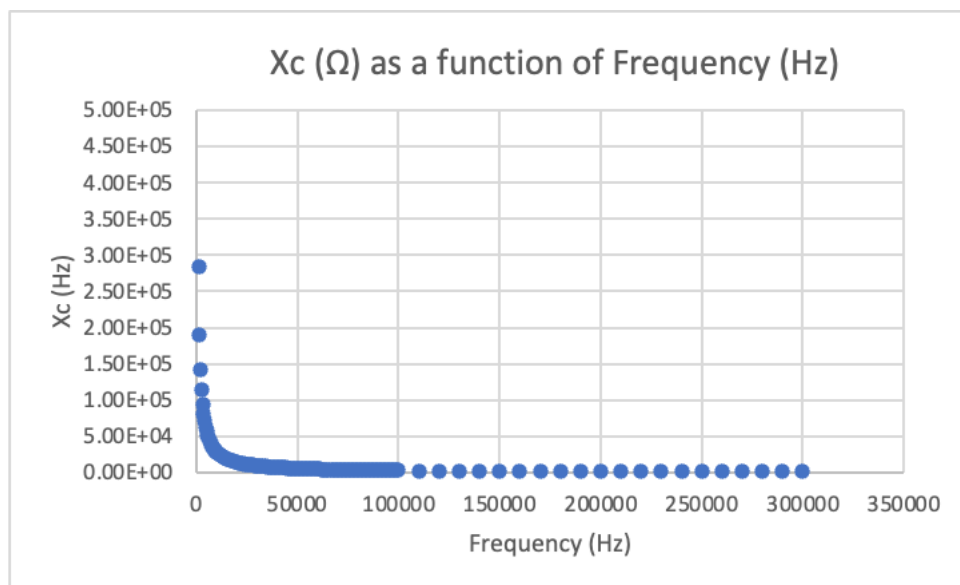


Figure 3: Low Pass Filter RC Circuit graph showing theoretical X_c (Ω) as a function of Frequency (Hz)

The results of the above graph (Figure 3) show theoretical data collected from incorporating a set of equations in to theoretical values. The graph portrays a sharp decline in X_c until the -3db cut-off at which the graph begins smoothening out.

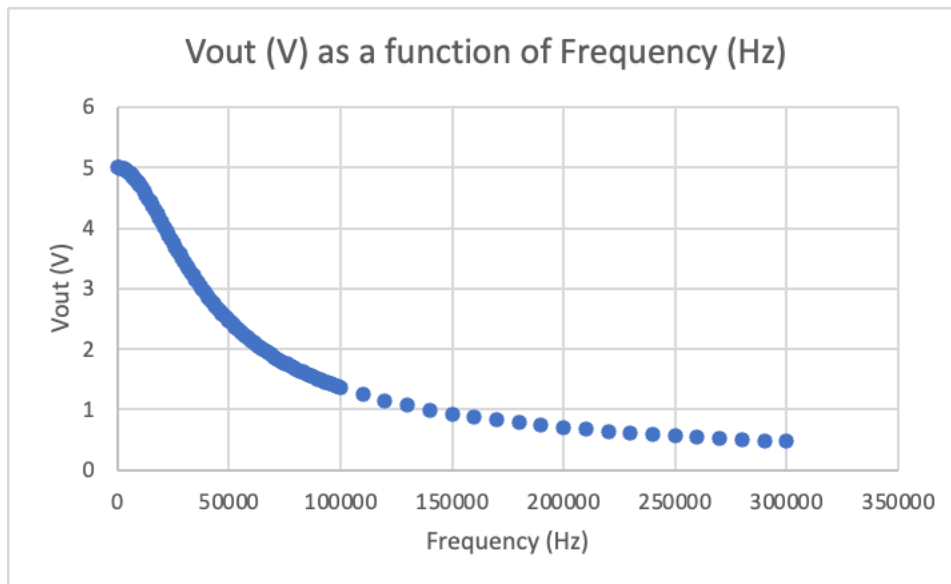


Figure 4: Low Pass Filter RC Circuit graph showing theoretical Vout (V) as a function of Frequency (Hz)

Shown above (Figure 4) is the theoretical results for vout (V) as a function of Frequency (Hz) in a Low Pass RC Filter Circuit, the graph displays a parabola that flattens out towards the higher end of the frequency values.

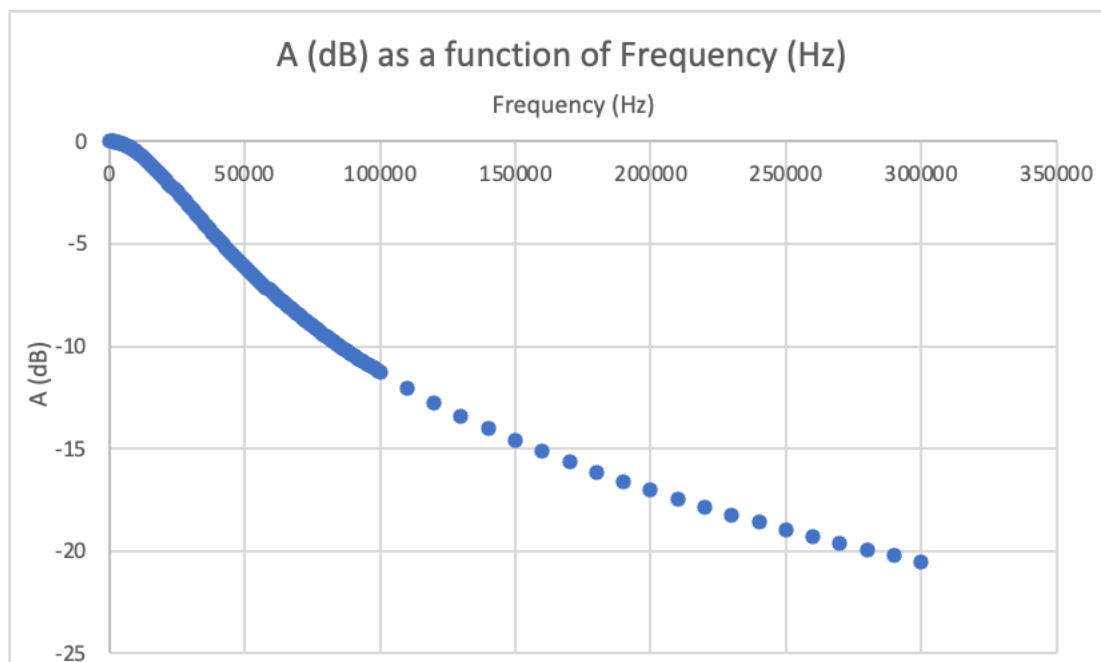


Figure 5: Low pass Filter RC Circuit graph showing theoretical A (dB) as a function of Frequency (Hz)

Here (Figure 5) we see a graph displaying where the theoretical -3db cut-off happens, the exact point at which this happens will be explained further in the discussion section of this report.

4.2 Low Pass Filter RC Circuit Experimental Results

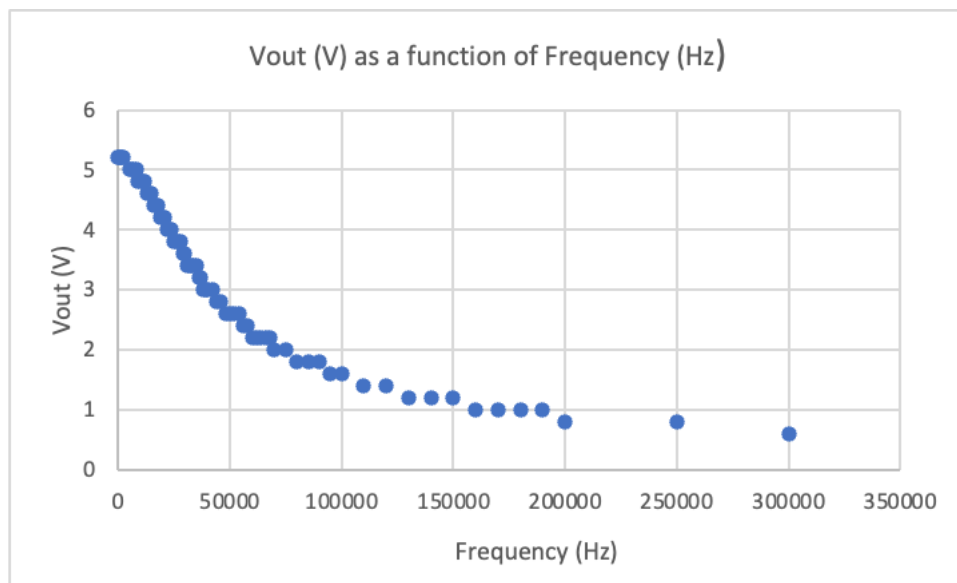


Figure 6: Low Pass Filter RC Circuit graph showing experimental Vout (V) as a function of Frequency (Hz)

The graph above (Figure 6) displays experimental results of vout (V) as a function of Frequency (Hz). The parabola of this graph is not dissimilar to that of the experimental results, the only noticeable difference is the smoothness of the line due to tolerances of components and the impedance of the circuit. These factors meant the small inconsistencies with vout values were out of our control.

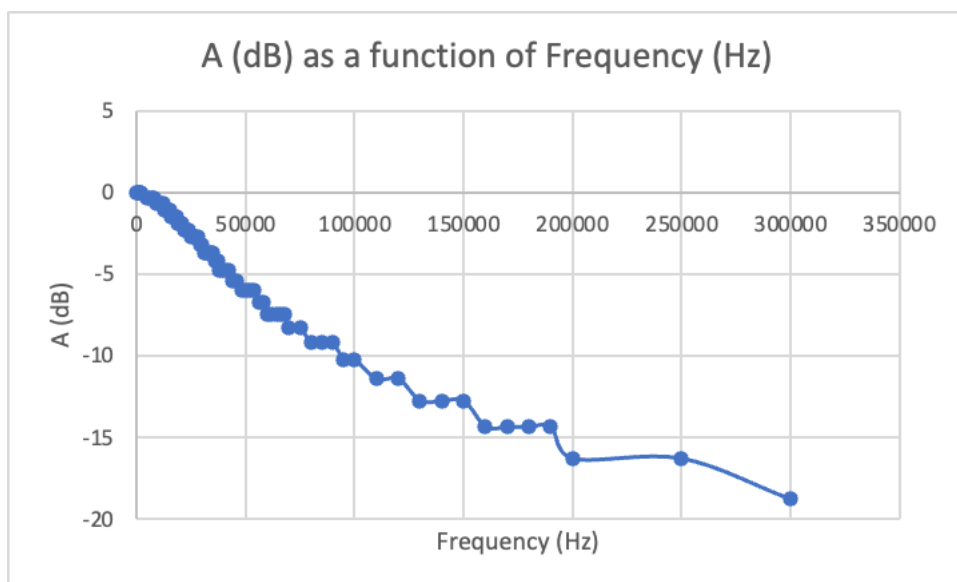


Figure 7: Low pass Filter RC Circuit graph showing experimental A (dB) as a function of Frequency (Hz)

Above exhibits a graph showing the experimental attenuation (Db) as a function of Frequency (Hz) (Figure 7). The graph shows similarities to figure 5, however like the previous graph the parabola is slightly disrupted due to tolerances of components and the impedance passing through the circuit.

4.3 High Pass Filter RC Circuit Theoretical Results

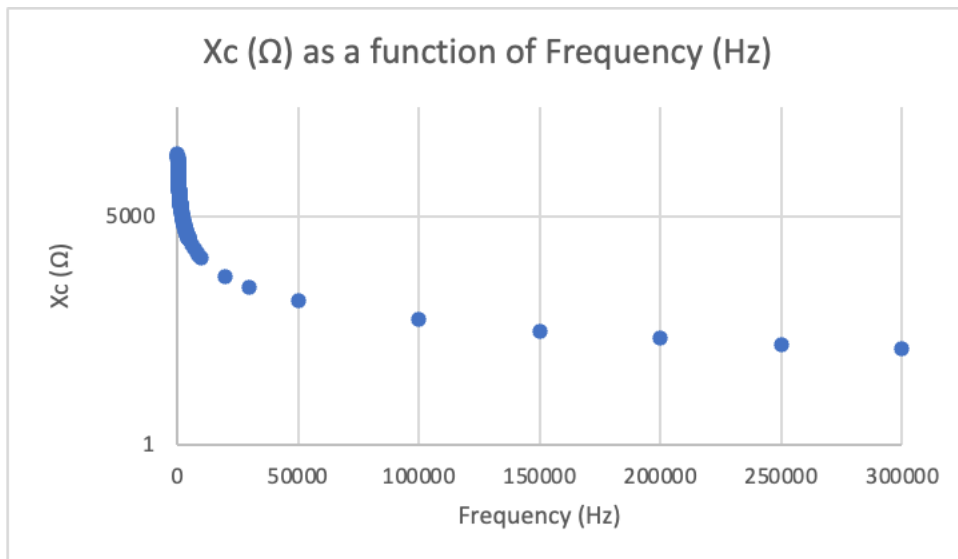


Figure 8: High Pass Filter RC Circuit graph showing theoretical X_c (Ω) as a function of Frequency (Hz)

The graph above (Figure 8) presents theoretical results of X_c as a function of Frequency for a high pass RC filter circuit, it depicts a steep decline in X_c value at low frequencies but evens out at higher frequencies due to the nature of a high pass RC filter circuit.

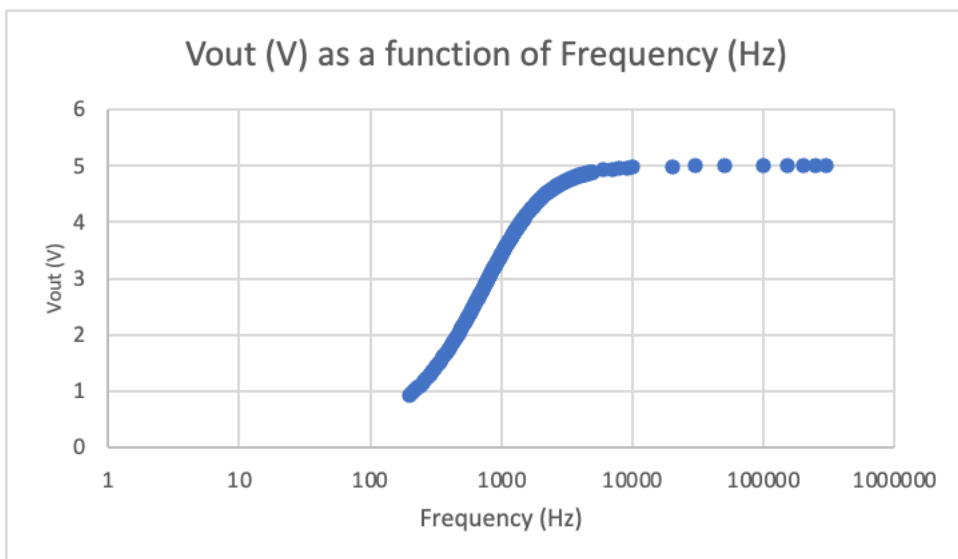


Figure 9: High Pass Filter RC Circuit graph showing theoretical V_{out} (V) as a function of Frequency (Hz)

Above (Figure 9) is a depiction of the theoretical V_{out} against frequency of a high pass RC filter circuit, this graph shows a steep increase of V_{out} at low frequencies which then flattens out at higher frequencies, the behaviour of this graph is inversely proportional to the that of the graph before (Figure 8).

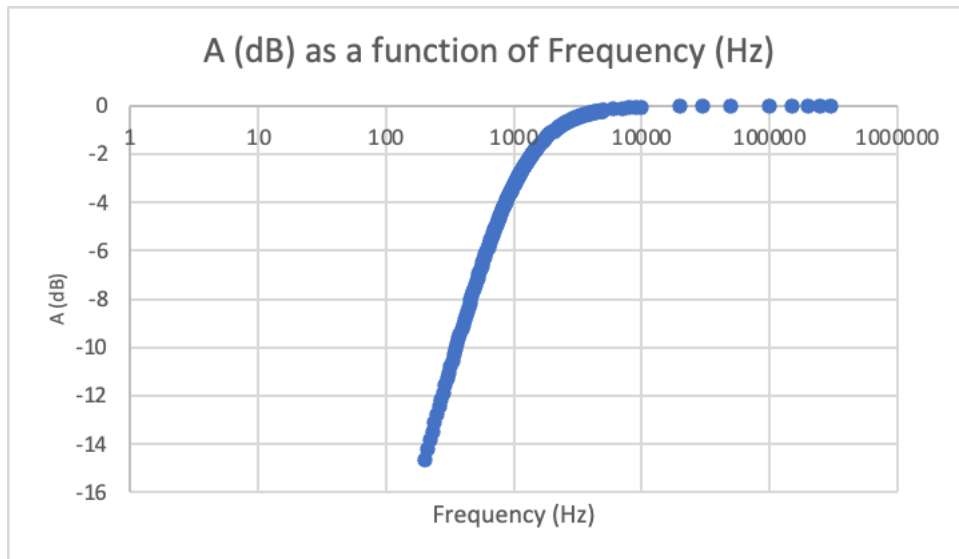


Figure 10: High pass Filter RC Circuit graph showing theoretical A (dB) as a function of Frequency (Hz)

This graph (Figure 10) shows the theoretical data collected of Attenuation as a function of Frequency, the graph is consistent with the theory of attenuation being higher at low frequencies when testing on a high pass filter RC circuit.

4.4 High Pass Filter RC Circuit Experimental Results

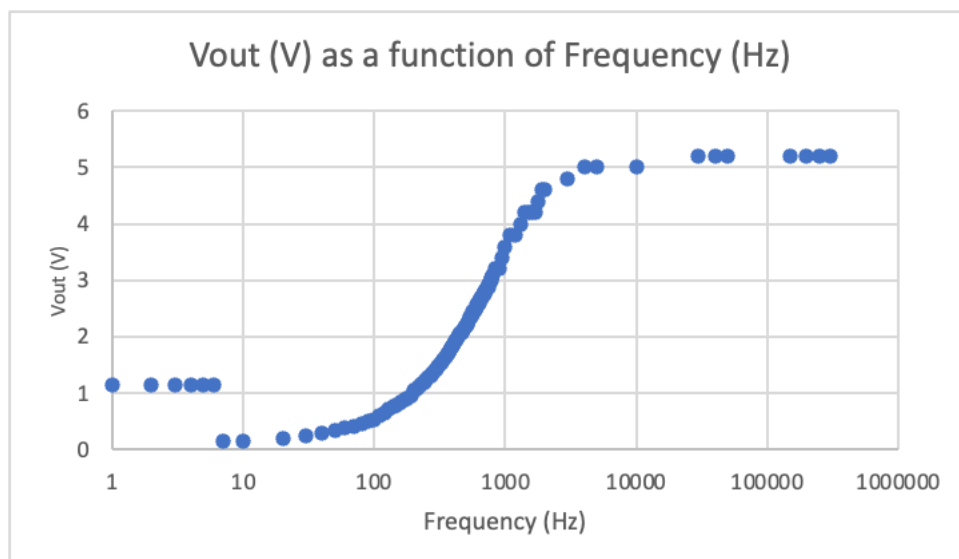


Figure 11: High Pass Filter RC Circuit graph showing Experimental Vout (V) as a function of Frequency (Hz)

Above (Figure 11) is a depiction of real experimental results collected through testing vout as a function of frequency on a high pass RC filter circuit. The graph shows similarities with the other theoretical values meaning the experiment was carried out correctly, the only difference to be spotted is the slight anomalies in the parabola, this would have been caused by component tolerances and the impedance of the circuit.

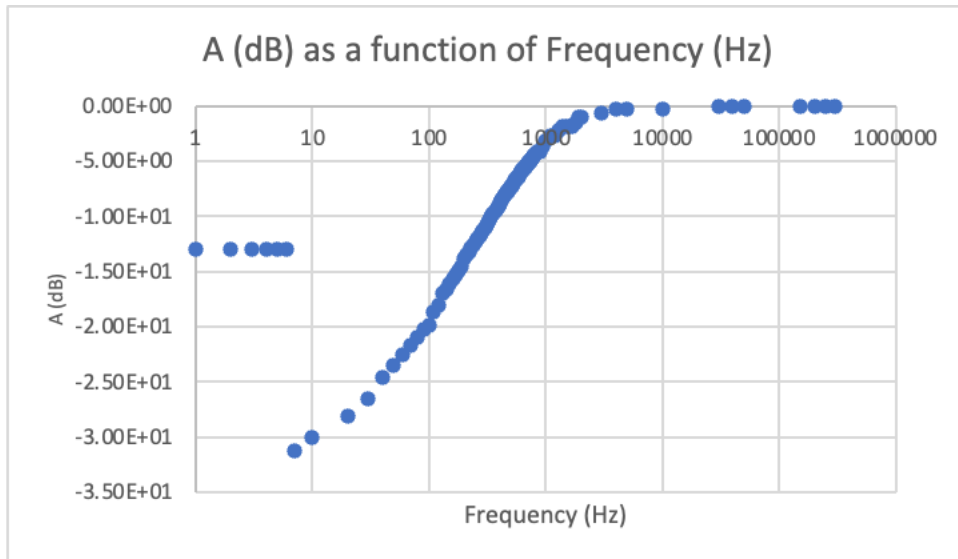


Figure 12: : High pass Filter RC Circuit graph showing Experimental A (dB) as a function of Frequency (Hz)

The final graph of this report (Figure 12) displays the second set of results collected from the high pass RC filter circuit experiment. The above data is consistent to that shown in the theoretical results (Figure 10), like all the experimental results there is anomalies when in comparison to the theoretical results which is caused by component tolerances and the impedance of the circuit.

5 Discussion

The discussion section of this report will summarise and explain the results taken from both theoretical and experimental tests on the RC filter circuits. The theoretical and experimental results will undergo comparisons, to which explanations for values and differences will be made clear to the reader.

5.1 Low Pass Results Discussion

To begin the discussion, the first graph (Figure 1) will undergo some analysis. The graph depicts a high theoretical X_c value at low frequencies, this is due to low pass circuits allowing a free flow of signals to be passed through at low frequencies. The X_c undergoes a steep decrease from frequencies between 100Hz to 28kHz, but then begins to even out due to -3dB cut-off being achieved at 29kHz. From here the X_c decreases in smaller increments as the frequency is increased.

The second theoretical graph for the low pass filter circuit (Figure 2) depicts V_{out} against Frequency. The results observed a gradual decrease in V_{out} as the frequency and attenuation increased, this makes sense for the low pass circuit as the increase of frequency is reflected in an increase in attenuation, which in-turn decreases the V_{out} as attenuation acts as the blocking force of signals (as previously stated). This graph is comparative to the results obtained in the real low pass experiment, the -3dB cut-off point for the theoretical tests took place at 29kHz, in which the V_{out} was 3.5V. The experimental data displays the V_{out} at 29kHz which returned a V_{out} of 3.6V. These values fall within the 10% tolerance of the components indicating a fair and reliable test. Another explanation for the differences was the impedance of the circuit, the V_{in} for the theoretical circuit was set to 5V whereas the V_{in} of the experimental circuit was always set to 5.2V.

To finish the discussion section on the low pass RC filter circuit, the attenuation against frequency will be compared for both theoretical and experimental experiments. Each graph (Figures 5&7) displays a smooth negative parabola which provides evidence for the attenuation decreasing as the frequency increases, the impact of this shows a direct link between frequency and attenuation on low pass RC filter circuits. The -3dB cut-off happens at 29kHz for both sets of results which is an obvious indication of a fair and reliable experiment.

5.2 High Pass Results Discussion

High pass RC filter circuits act inversely to low pass RC filter circuits in the way that they display low attenuation values at high frequencies.

The first graph of the high pass circuit was that showing the theoretical X_c against frequency (Figure 8). The graph depicts a high X_c value which falls at a high rate; however, this begins to even out as the frequency increases due to the attenuation working inversely with the capacitance. As we know, the attenuation decreases as frequency increases due to high pass RC filter circuits attenuating lower frequencies.

The next set of comparisons to be made will be V_{out} as a function of frequency in both the theoretical and experimental field. Each graph (Figures 9 & 11) depicts a rapid increase of V_{out} at low frequencies, but the rate does slow down as the frequency reaches the -3dB cut-off. The reason for these results is due to the attenuation (blocking catalyst) of the circuit being high when the frequency is low, this is expected as the purpose of a high pass filter is to block low frequency signals. The experimental and theoretical results display a highly similar pattern which adds to the validity of the experiments, however the small anomalies within figure 11 are caused by the tolerances of components alongside the impedance of the circuit. To further add to the anomalies, the V_{in} values of the experimental test varied from 5.2V (300kHz to 850Hz) to 5.12V (800Hz to 1Hz) whereas the theoretical data used a constant 5V V_{in} value across all frequencies.

To close the discussion section of this report, the theoretical and experimental attenuation graphs for the high pass RC filter circuits (Figures 10 & 12) will be compared and explained. The theoretical results of display a -3dB cut-off 1060 Hz whereas this is achieved at 1000Hz during the experiment. There can be several factors which may have a direct affect the anomaly between both results. Firstly, like all experiments, tolerances of components alongside the impedance of the circuit must be considered, also the variation of V_{in} across the circuit (as previously stated). Despite this, the attenuation graphs provide reliable data in-line with prior theory of attenuation being higher at low frequencies.

6 Conclusion

In this experiment, it has been determined that the experimental and theoretical results share similarities indicating a fair set of assessments were carried out.

The low pass filter RC circuit results show -3dB cut-offs at 29kHz respectively as shown in figures 5 and 7, this concludes the theory of low pass filter circuits producing greater attenuation at higher frequencies. The result of attenuation increasing alongside frequency provides a direct link to the reduction in capacitance and V_{out} due to attenuation being the blocking factor of signals.

The anomalies between theoretical and experimental results were found to be caused by multiple reasons, firstly the input voltages were different, 5V (theoretical) and 5.2V (experimental) respectively which had a knock-on effect on other values. The tolerances of components were also a determining factor in the variation of results so a 10% +/- difference would be deemed a fair experiment.

The same theory goes for the high pass circuits, attenuation is the key factor in determining V_{out} and X_c . As previously explained, the attenuation will be higher at low frequencies when testing high pass circuits due to their nature of blocking low frequency signals. The attenuation would gradually increase as the frequency decreased, this was shown in both theoretical and experimental tests which further backed the theory explained previously. The -3dB cut-offs of the high pass circuits did show little variation much like the low pass circuits, 1060Hz and 1100Hz respectively. These values fall within the 10% tolerance figure which solidifies the integrity of the experiments, especially when coupled with the different V_{in} values, 5V (theoretical) and 5.12-5.2V (experimental).

To conclude this report, the figures present consistencies with the common derived theories of high pass and low pass circuits. The results depict attenuation being high at high frequencies for low pass filters, and the inverse for low pass filters.

7 References

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