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Design of Filter Circuit

Electrical Principles (ACMA 4031)

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1. Executive Summary

This experiment evaluates the attenuation characteristics of a first order RC low-pass and high-pass filter across a range of frequencies. The purpose of this experiment is to evaluate its attenuation characteristic across a range of frequencies. For each circuit, the signal generator output was set, once set the output amplitude was not changed. Where A is attenuation in dB, V_{in} is the peak-to-peak voltage measured across the input of each circuit, and V_{out} is the peak-to-peak output voltage for each circuit.

The Proteus simulation provided an idealised reference curve for both low-pass and high-pass, while the breadboard experiment demonstrated how the same filter behaves under real conditions. Despite minor deviations caused by component tolerances and breadboard parasitic, the physical circuit closely matched the theoretical and simulated response.

This agreement confirms that the filter was constructed correctly and that the measured behaviour is consistent with the expected characteristics of a first-order RC high-pass filter.

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3. Introduction

3.1. Low-pass Filter (LPF)

A low-pass filter, often used in audio processing, allows frequencies below the cut off frequency to pass through while attenuating frequencies above the cutoff frequency. When the input signal frequency is low, the capacitor impedance is high relative to the resistor, therefore the input voltage drops across the capacitor. Alternatively, when the input frequency is high, the capacitor impedance is low in relation to the resistor, allowing more voltage drops across the resistor, where low frequencies pass through and high frequencies are blocked.

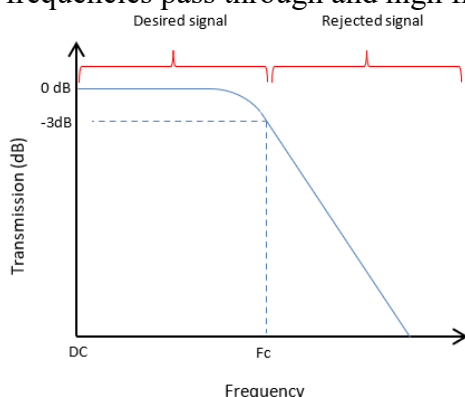


Figure 1. Low-pass Filter from Electrical Principles ACMA 4031, Lecture – 10, slide 14. (Jacobs, 2026)

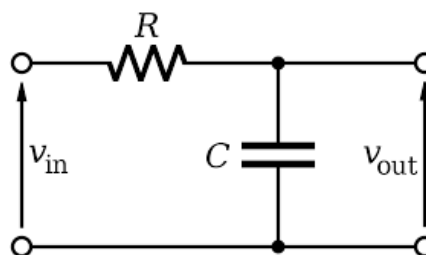


Figure 2. Low-pass Filter Circuit from Electrical Principles ACMA 4031, Lecture – 10, slide 15. (Jacobs, 2026)

3.2. High-pass Filter (HPF)

A high-pass filter, used in audio processing, allows frequencies above a certain cutoff frequency to pass through while attenuating frequencies below the cutoff.

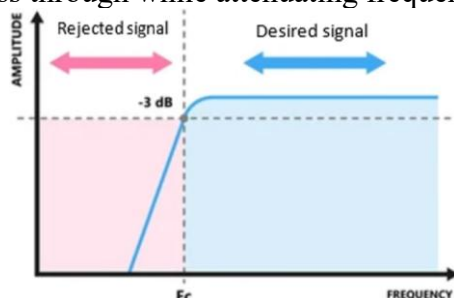


Figure 3. High-pass Filter from Electrical Principles ACMA 4031, Lecture – 10, slide 16. (Jacobs, 2026)

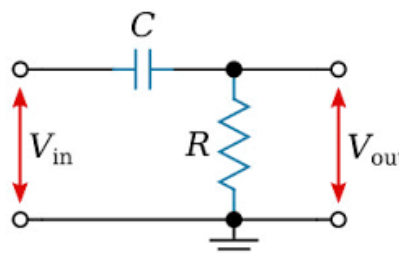


Figure 4. High-pass Filter Circuit from Electrical Principles ACMA 4031, Lecture – 10, slide 17. (Jacobs, 2026)

3.3. Cutoff Frequency

Cut off frequency (f_c), defined as the frequency at which the power of the signal is reduced to half of its original value, is the specific frequency point where a circuit starts to reduce or attenuate the intensity of the signal.

Equation 1. RC Filter Cutoff. (Bird, 2010)

$$f_c = \frac{1}{2\pi RC}$$

3.4. Attenuation

Attenuation (dB) in an RC circuit refers to the reduction of the amplitude of the signal as it passes through the circuit. Measured input voltage V_{in} and output voltage V_{out} are used to calculate the attenuation at each frequency using the formula:

Equation 2. Attenuation. (Bird, 2010)

$$A = 20 \log_{10} \left(\frac{V_{out}}{V_{in}} \right)$$

4. Experiment

This experiment evaluates the attenuation characteristics of a first order RC low-pass and high-pass filter across a range of frequencies.

For each circuit, the signal generator output was set, once set the output amplitude was not changed. Where A is attenuation in dB, V_{in} is the peak-to-peak (pk-pk) voltage measured across the input of each circuit, and V_{out} is the peak-to-peak output voltage for each circuit.

4.1. Method 1

In proteus, a signal generator was set and then connected to channel A of an oscilloscope, where the waveform was displayed. One full cycle, pk-pk, is measured using the time cursors, allowing to determine the time period (T).

4.1.1. Low-pass Filter

The low-pass filter was applied using a 10 k Ω resistor and a 560 pF capacitor, giving a theoretical cutoff frequency of 28,420 Hz.

A 4 V pk-pk sinusoidal input signal was applied using the Proteus signal generator, and the output waveform was measured using the oscilloscope. The input frequency was increased from 100 Hz to 300 kHz, and the output amplitude was calculated at each point.

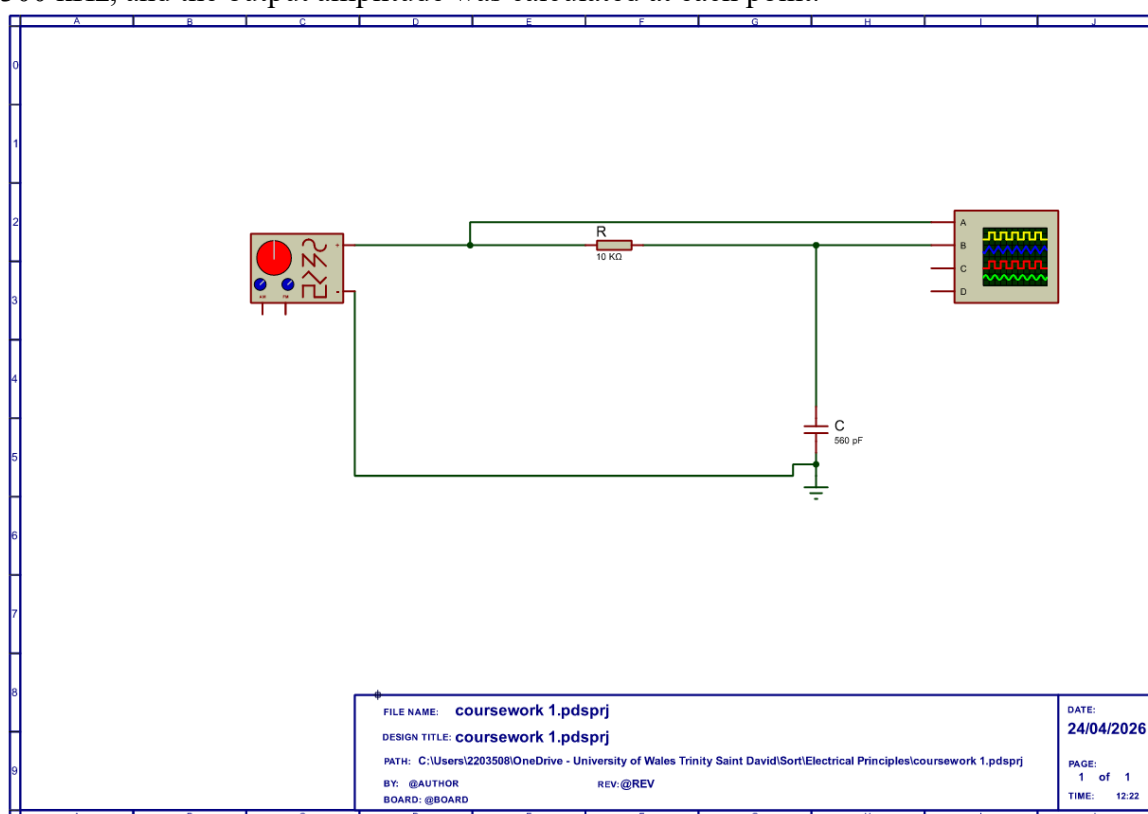


Figure 5. Dowling, E. Mark-up of a Low-Pass Filter Circuit, Proteus 8, 24.04.2026.

4.1.2. High-pass Filter

The high pass filter was implemented using a $10\text{ k}\Omega$ resistor and a 15 nF capacitor, corresponding to a theoretical cutoff frequency 1061 Hz .

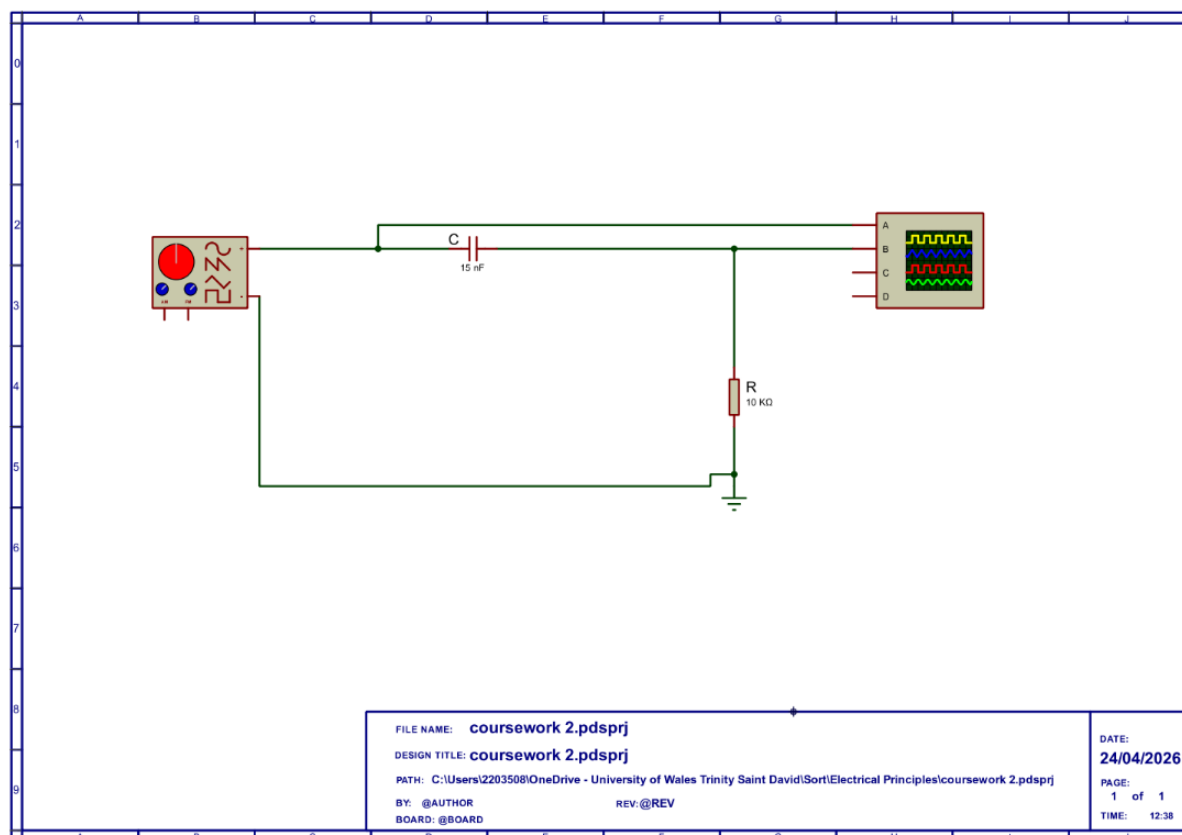


Figure 6. Dowling, E. Markup of a High-pass Filter Circuit. Dated 24.04.2026.

The circuit was constructed in Proteus and examined using an oscilloscope. A sinusoidal input signal of 4 V pk-pk was applied from the signal generator, beginning at 100 Hz and increasing logarithmically up to 300 kHz . For each frequency, the output amplitude was measured and the gain in decibels was calculated.

4.2. Method 2

4.2.1. Low-pass Filter

The low-pass filter was constructed on a solderless breadboard using a $10\text{ k}\Omega$ resistor and a 560 pF capacitor, giving a theoretical cutoff frequency of $28,420\text{ Hz}$.

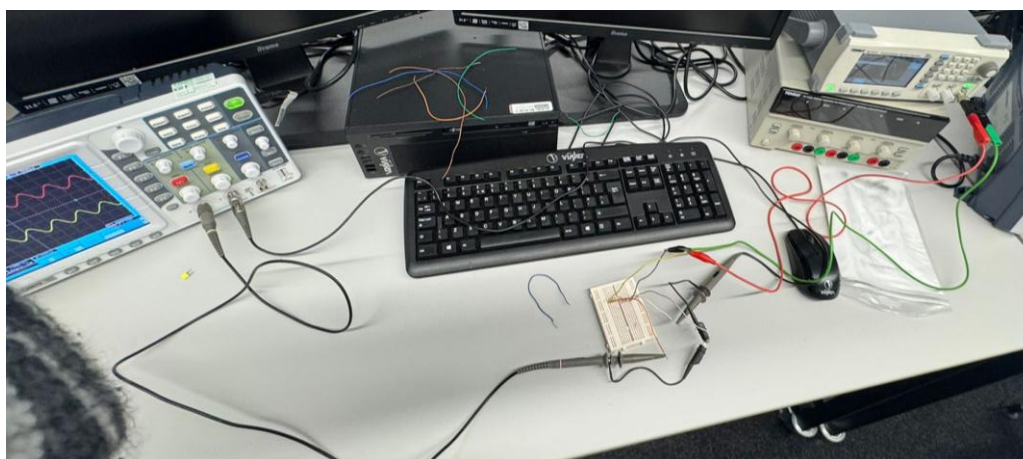


Figure 7. Dowling, E. Low-pass Filter Circuit on a Solderless Breadboard, connected to an Oscilloscope.

A 4 V pk-pk sinusoidal input was applied from the signal generator, initially set at 100 Hz, and the output waveform was measured using a digital oscilloscope. The input frequency was increased from 100 Hz to 300 kHz, and the output amplitude was recorded at each step. The gain in decibels was calculated.

4.2.2. High-pass Filter

The high-pass filter was constructed on a solderless breadboard using a 10 k Ω resistor and a 15 nF capacitor, giving a theoretical cutoff frequency of 1061 Hz.

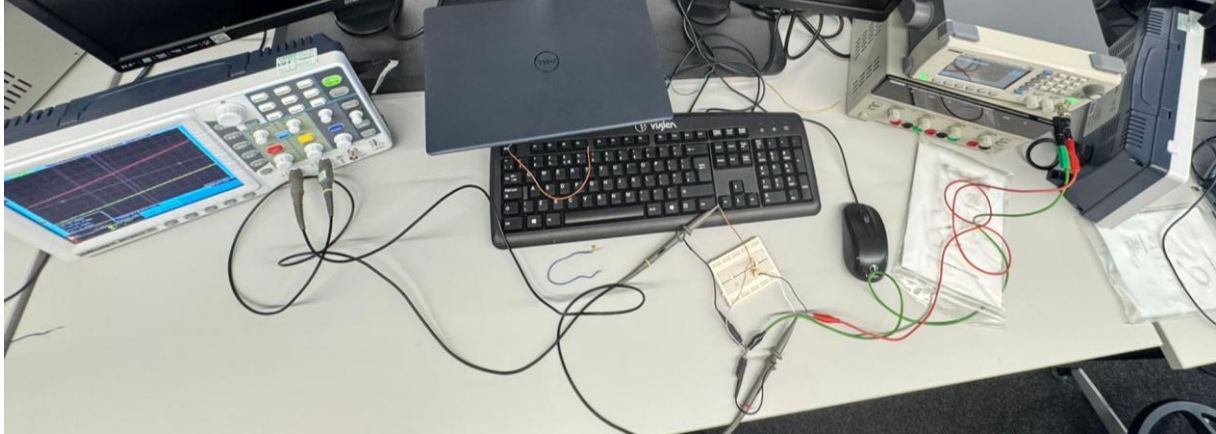


Figure 8 Dowling, E. High-pass Filter Circuit on a Solderless Breadboard, connected to an Oscilloscope.

A 4 V pk-pk sinusoidal input was supplied from a signal generator, and the output waveform was measured using a digital oscilloscope. The frequency was swept from 100 Hz to 300 kHz, and for each point the output amplitude was recorded. The gain in decibels was calculated.

5. Results

Following both Method 1 and 2, the input and output peak-to-peak voltages were measured over a range of frequencies from 100 Hz to 300 kHz. The cutoff region, as stated previously, is the -3 dB point; where several closely measurements were taken to determine the cutoff points accurately. Additional measurements were taken between 27,000 Hz and 29,000 Hz (low-pass), and 950 Hz and 1,150 Hz (high-pass) to identify more accurately the -3db cutoff, this could not be measured using Method 1.

Attenuation was calculated for each frequency using the equation noted in both Methods 1 and 2. The results are under column $20 \cdot \text{LOG}_{10}(V_{\text{out}}/V_{\text{in}})$ included in Figures 9, 10, 11, and 12.

5.1.Method 1

Low pass Filter			
F (Hz)	V _{in}	V _{out}	$20 \cdot \text{LOG}_{10}(V_{\text{out}}/V_{\text{in}})$
100	4	4	0
500	4	4	0
1,000	4	4	0
5,000	4	4	0
10,000	4	3.8	-0.445527894
20,000	4	3.2	-1.93820026
25,000	4	3	-2.498774732
26,000	4	3	-2.498774732
26,500	4	2.9	-2.793239869
27,000	4	2.9	-2.793239869
27,500	4	2.87	-2.883561892
28,000	4	2.84	-2.974833026
28,500	4	2.82	-3.03621766
29,000	4	2.79	-3.129115761
29,500	4	2.77	-3.191604445
30,000	4	2.75	-3.25454595
50,000	4	2	-6.020599913
100,000	4	1	-12.04119983
200,000	4	0.6	-16.47817482
300,000	4	0.4	-20

Cutoff frequency is $F_c = 1/2\pi RC$, therefore the cutoff frequency = 28,420Hz

Figure 9. Dowling, E. Screenshot of the Low-pass Filter Circuit Theoretical Results calculated through Excel.

High pass Filter			
F (Hz)	V _{in}	V _{out}	$20 \cdot \text{LOG}_{10}(V_{\text{out}}/V_{\text{in}})$
100	4	0.38	-20.44552789
200	4	0.74	-14.65656543
300	4	1.07	-11.45352427
400	4	1.38	-9.243618099
500	4	1.67	-7.586870404
600	4	1.94	-6.285165228
700	4	2.17	-5.31200515
800	4	2.38	-4.509660685
900	4	2.56	-3.87640052
950	4	2.64	-3.609121289
1000	4	2.74	-3.28618857
1050	4	2.83	-3.005471116
1100	4	2.9	-2.793239869
1150	4	2.97	-2.58607084
1200	4	3.03	-2.412347257
1500	4	3.26	-1.776847825
2000	4	3.54	-1.061134586
3000	4	3.77	-0.514372822
5000	4	3.91	-0.197664679
10000	4	3.98	-0.043538385
50000	4	4	0
100000	4	4	0
200000	4	4	0
300000	4	4	0

Cutoff frequency is $F_c = 1/2\pi RC$, therefore the cutoff frequency = 1,061Hz

Figure 10. Dowling, E. Screenshot of the High-pass Filter Circuit Theoretical Results calculated through Excel.

5.1.1. Low-pass Filter

At low frequencies, the output voltage remained equal to the input voltage. This is consistent with the theoretical expectation that at frequencies below the cutoff, the capacitor presents a low reactance relative to the resistor, allowing the input signal to pass to the output with minimal attenuation.

The measured -3 dB point occurred close to the calculated cutoff frequency, confirming that the component values and circuit configuration were correctly implemented.

At frequencies significantly above the cutoff, the output voltage dropped sharply, where this behaviour reflects the expected attenuation slope of a first-order RC low-pass filter.

5.1.2. High-pass Filter

At frequencies below the cutoff the output amplitude remained significantly attenuated. This behaviour is consistent with the theoretical expectation that; at low frequencies, the capacitor presents a high reactance and therefore blocks most of the input signal. The filter therefore behaves as a strong attenuator in this region.

As the input frequency approached the calculated cutoff, the output amplitude increased steadily.

At frequencies above the cutoff, the output amplitude approached the full input amplitude of 4 V pk-pk, and the calculated gain tended toward 0 dB. This plateau indicates that the filter had reached its passband, where the capacitor's reactance is sufficiently small that the circuit behaves almost like a direct connection between input and output.

5.2. Method 2

Low pass Filter			
F (Hz)	V _{in}	V _{out}	20*LOG ₁₀ (V _{out} /V _{in})
100	4	4	0
500	4	4	0
1,000	4	4	0
5,000	4	4	0
10,000	4	3.6	-0.915149811
20,000	4	3.12	-2.158107946
25,000	4	2.88	-2.853350071
26,000	4	2.8	-3.0980392
26,500	4	2.8	-3.0980392
27,000	4	2.8	-3.0980392
27,500	4	2.72	-3.349821746
28,000	4	2.72	-3.349821746
28,500	4	2.72	-3.349821746
29,000	4	2.64	-3.609121289
29,500	4	2.64	-3.609121289
30,000	4	2.56	-3.87640052
50,000	4	0.48	-18.41637508
100,000	4	0.48	-18.41637508
200,000	4	0.48	-18.41637508
300,000	4	0.4	-20

Cutoff frequency is $F_c = 1/2\pi RC$, therefore the cutoff frequency = 28,420Hz

Figure 11. Dowling, E. Screenshot of the Low-pass Filter Circuit Practical results calculated through Excel.

High pass Filter			
F (Hz)	V _{in}	V _{out}	20*LOG ₁₀ (V _{out} /V _{in})
100	4.00	0.48	-18.41637508
200	4.00	0.80	-13.97940009
300	4.00	1.12	-11.05683937
400	4.00	1.44	-8.873949985
500	4.00	1.76	-7.13094647
600	4.00	2.00	-6.020599913
700	4.00	2.24	-5.03623946
800	4.00	2.40	-4.436974992
900	4.00	2.56	-3.87640052
950	4.00	2.64	-3.609121289
1000	4.00	2.72	-3.349821746
1050	4.00	2.80	-3.0980392
1100	4.00	2.88	-2.853350071
1150	4.00	2.96	-2.615365605
1200	4.00	2.96	-2.615365605
1500	4.00	3.28	-1.723722952
2000	4.00	3.52	-1.110346557
3000	4.00	3.76	-0.537442928
5000	4.00	4.00	0
10000	4.00	4.00	0
50000	4.00	4.00	0
100000	4.00	4.00	0
200000	4.00	4.00	0
300000	4.00	4.00	0

Cutoff frequency is $F_c = 1/2\pi RC$, therefore the cutoff frequency = 1,061Hz

Figure 12. Dowling, E. Screenshot of the High-pass Filter Circuit Practical results calculated through Excel.

5.2.1. Low-pass Filter

At frequencies well below the cutoff, the output voltage remained equal to the input, corresponding to a gain of 0 dB. This confirms that the filter passed low-frequency signals with small attenuation, as expected for a first-order RC low-pass network.

As the input frequency approached the theoretical cutoff of 28,420 Hz, the output amplitude began to fall. Between 27 kHz and 29.5 kHz, the output decreased from 2.88 V to 2.64 V. The measured -3 dB point occurred close to the predicted cutoff frequency, demonstrating that the physical circuit behaved consistently with theoretical expectations despite component tolerances.

5.2.2. High-pass Filter

At low frequencies, the breadboard circuit exhibited strong attenuation, with output voltages between 0.48 V and 2.56 V.

As the input frequency approached the theoretical cutoff 1,061 kHz, the output amplitude increased rapidly. Between 950 Hz and 1,500 Hz, the measured output increased from 2.64 V to 2.96 V.

At frequencies above approximately 3 kHz, the output voltage stabilised at the full 4 V pk-pk input amplitude, giving a gain of 0 dB across the remainder up to 300 kHz. This confirms that the circuit had reached its passband and the flatness of the passband suggests that parasitic inductances and capacitances of the breadboard did not significantly distort the response within the tested frequency range.

6. Discussion

6.1. Low-pass Filter

Both the simulated and physical circuits demonstrated the expected characteristics of a first-order RC low-pass filter built from a 10 k Ω resistor and 560 pF capacitor, with a theoretical cutoff frequency of approximately 28.4 kHz. In both cases, the output remained equal to the input at low frequencies, it then began to attenuate around the cutoff region, and showed significant attenuation at higher frequencies, this is displayed by two fold within the graphs produced of the attenuation properties, refer to Appendix A.

Both systems behaved identically in the passband; the breadboard implementation matched the theoretical response closely, showing that the physical layout did not introduce significant low-frequency distortion.

Both circuits exhibited the correct high-frequency attenuation pattern. The breadboard showed slightly more variation, which is typical of real-world circuits where wiring length, probe capacitance, and component tolerances influence the response.

6.2. High-pass Filter

Both the Proteus simulation and the breadboard circuit produced the characteristic response of a first-order RC high-pass filter with a 10 k Ω resistor and 15 nF capacitor, and a theoretical cutoff frequency of approximately 1.06 kHz. The output was heavily attenuated at low frequencies, increased sharply around the cutoff region, and reached unity gain at higher frequencies.

The breadboard circuit attenuated low frequencies as expected, but not quite as strongly as the simulation. This is typical of real circuits, where component tolerances and breadboard parasitic slightly reduce attenuation. The breadboard circuit reached its effective cutoff a little sooner than the simulation. This is likely due to; capacitor tolerance, additional stray capacitance on the breadboard, or oscilloscope probe loading.

Both systems behaved almost identically at high frequencies, indicating that parasitic inductances and capacitances of the breadboard were not significant enough to affect the passband within the tested range.

7. Conclusion

The Proteus simulation provided an idealised reference curve for both low-pass and high-pass, while the breadboard experiment demonstrated how the same filter behaves under real conditions. Despite minor deviations caused by component tolerances and breadboard parasitic, the physical circuit closely matched the theoretical and simulated response.

This agreement confirms that the filter was constructed correctly and that the measured behaviour is consistent with the expected characteristics of a first-order RC high-pass filter.

8. References

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Appendix A

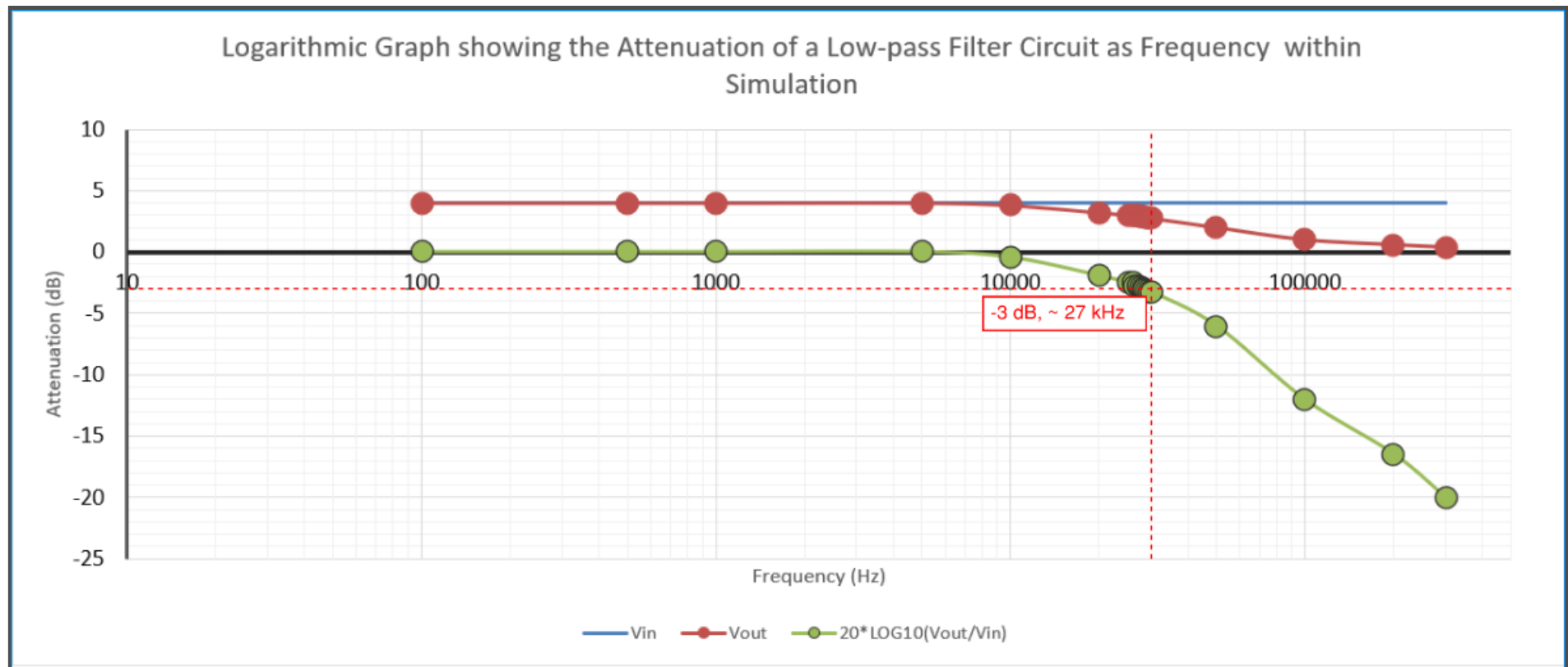


Figure 13. Logarithmic Graph showing the Attenuation of a Low-pass Filter Circuit as Frequency within Simulation

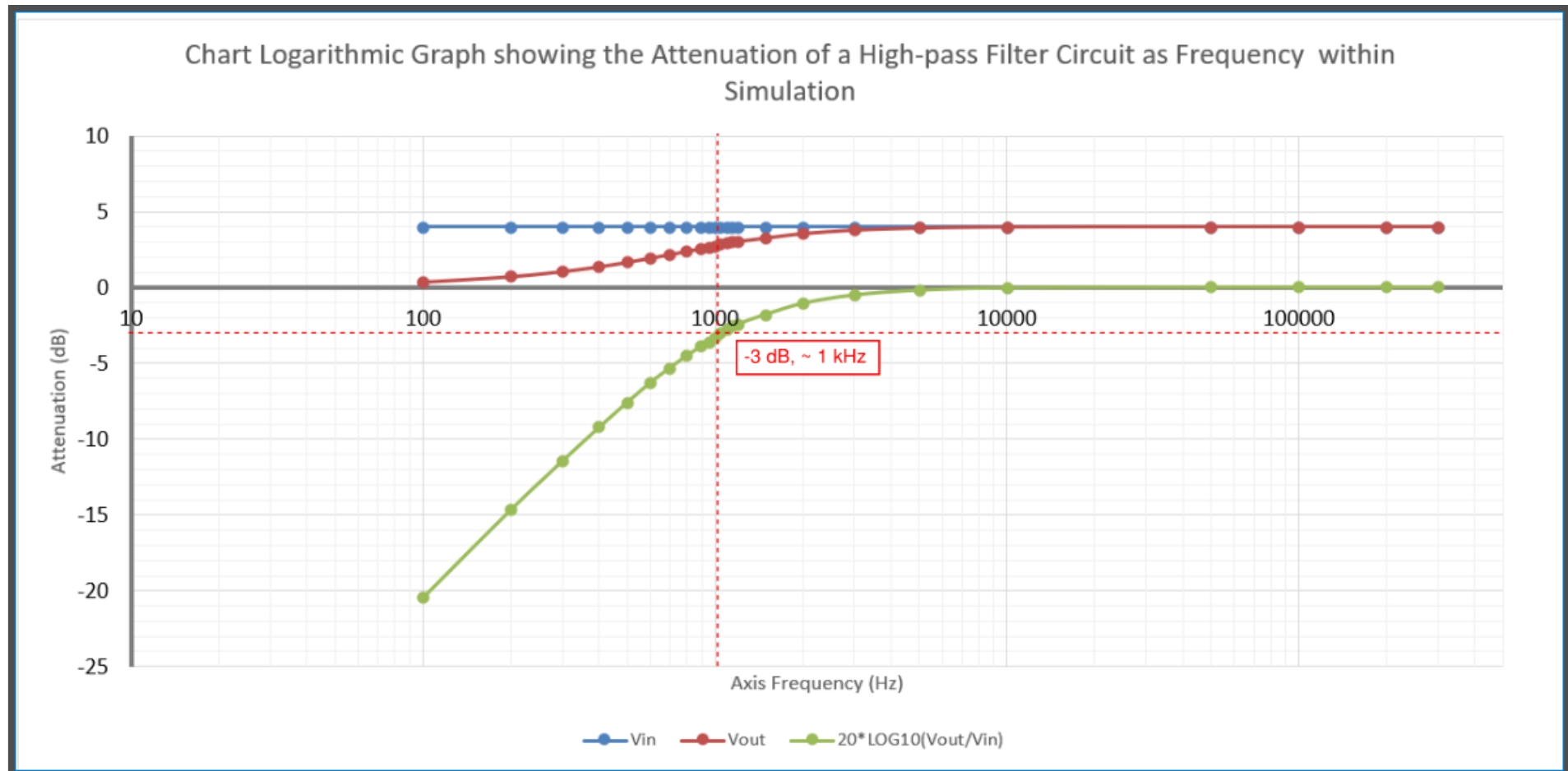


Figure 14. Logarithmic Graph showing the Attenuation of a High-pass Filter Circuit as Frequency within Simulation

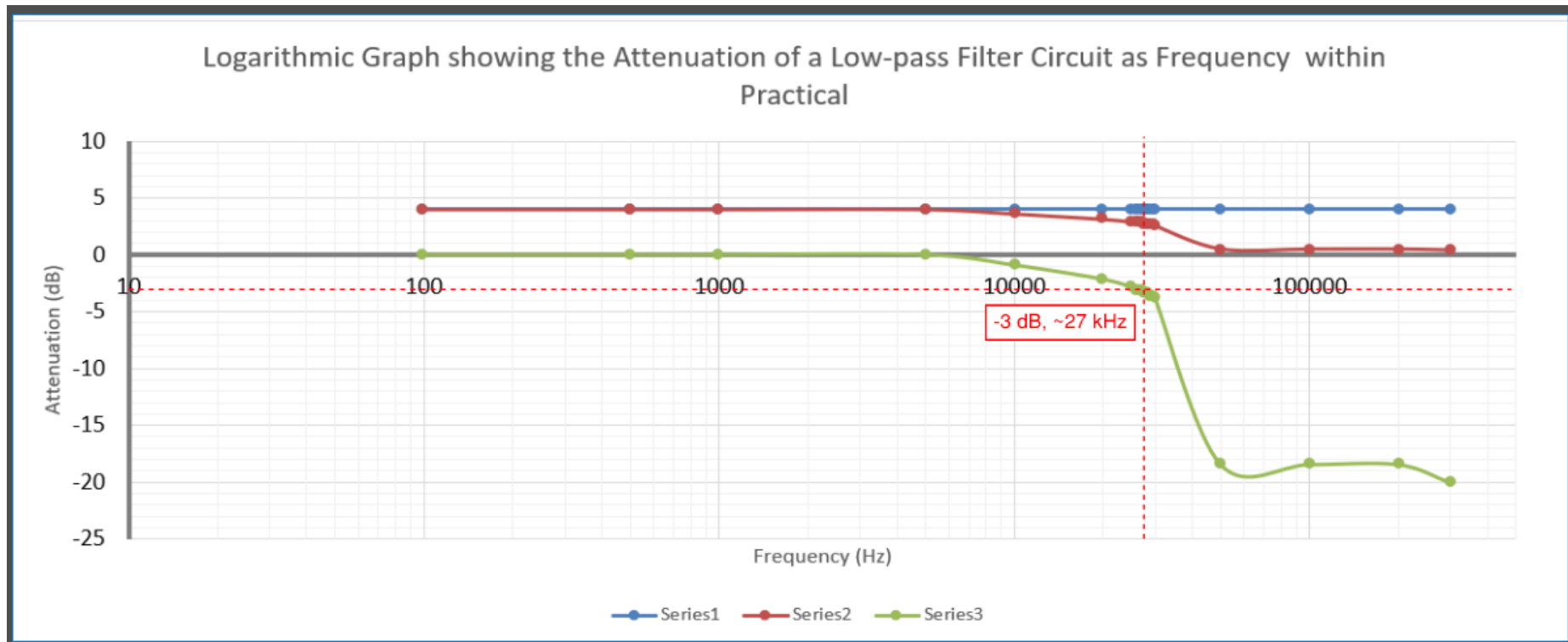


Figure 15. Logarithmic Graph showing the Attenuation of a Low-pass Filter Circuit as Frequency within Practical

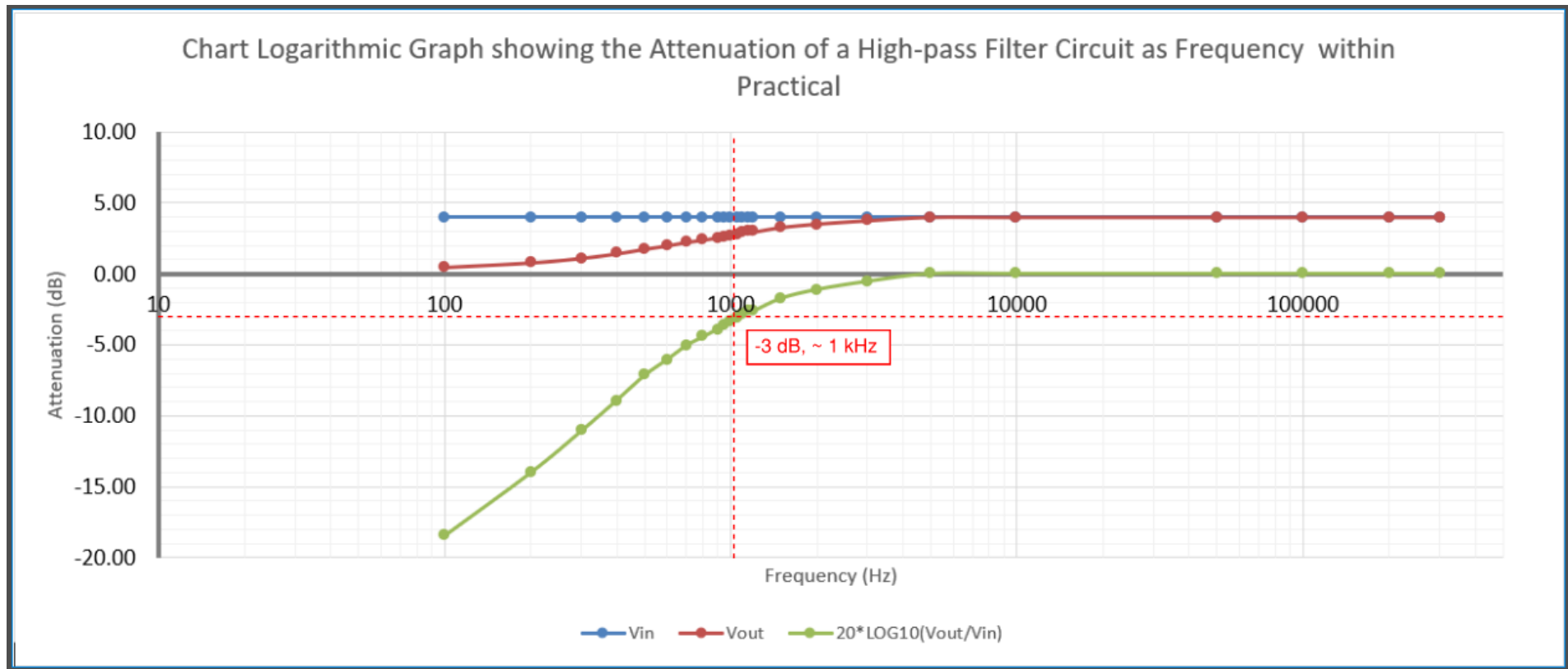


Figure 16. Logarithmic Graph showing the Attenuation of a High-pass Filter Circuit as Frequency within Practical

