Investigation of RC Circuit Driven by AC Current

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1 Introduction and Aim

To investigate the behavior of an RC circuit driven by AC current and understand the relationship between voltage, current, impedance, and frequency in the circuit.

2 Theory

In an AC circuit, the impedance of a resistor is $Z_R = R\angle 0\,\Omega$ and that of a capacitor is

$$Z_C = X_C\angle -90\,\Omega = \frac{1}{\omega C}\angle -90\,\Omega = \frac{1}{2\pi f C}\angle -90\,\Omega.$$

In a series RC circuit, the current is constant ($I = I_R = I_C$), the total impedance is

$$Z_T = Z_R + Z_C = R - jX_C,$$

and the source voltage equals the sum of the potential differences across the resistor and capacitor:

$$V_S = V_R + V_C.$$

The voltages across the resistor and capacitor form a potential divider:

$$V_C = \left(\frac{Z_C}{Z_C + Z_R}\right) V_S, \quad V_R = \left(\frac{Z_R}{Z_C + Z_R}\right) V_S.$$

The phase of V_R is in phase with the current, while V_C lags the current by 90 degrees. As the frequency increases, X_C decreases, reducing the total impedance and altering the voltage division ratio. These relationships are fundamental to analyzing the circuit's response to different frequencies.

3 Experimental Method and Results

3.1 Circuit Diagram The circuit diagram for the series RC circuit consists of a resistor (R), a capacitor (C), an AC voltage source (V_S), and connections to measure the voltages across the resistor (V_R) and capacitor (V_C).

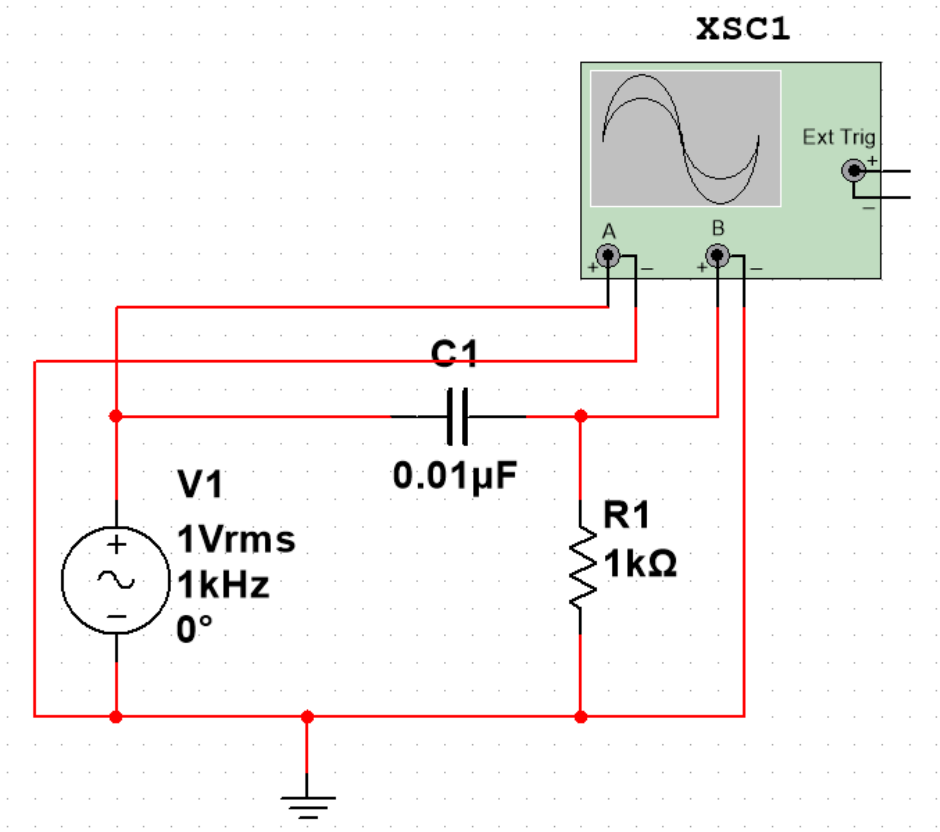

Figure 1: Series RC Circuit Diagram.

3.2 Experimental Method The experiment was carried out by first setting up the physical circuit on a breadboard. The AC voltage source from the function generator was adjusted to approximately 2 V at 1 kHz. Appropriate values of R and C were selected. The cathode ray oscilloscope (CRO) was used to measure the voltages. One channel of the CRO measured V_S, while the other was used to measure V_R and V_C by switching the connections. The peak values of V_S, V_R, and V_C were recorded, along with the time lags τ_R and τ_C with respect to the total voltage. The process was repeated at 5 kHz.

In the Multisim simulation, the circuit was designed using the software's component library. The AC source, resistor, and capacitor were placed and wired correctly. An oscilloscope was added to measure the voltages. The simulation was run, and the voltage and time lag values were measured and recorded.

V_S(V)	V_R(V)	V_C(V)	τ_R (ms)	τ_C (ms)	T (ms)	f (Hz)
2.00	1.00	1.73	0.00	-0.25	1.00	1000
2.00	1.79	0.90	0.00	-0.05	0.20	5000

Table 1: Experimental Results.

3.3 Results and Discussion The aim of understanding the circuit's behavior was achieved. The measured voltages and time lags showed the expected trends with frequency changes. For example, as frequency increased, V_C decreased and V_R increased, consistent with theory. However, there were some inaccuracies. Measurement errors from the CRO, such as parallax and limited precision, affected the voltage and time lag values. To improve, a higher precision CRO could be used. In the simulation, while results matched well, differences could be due to idealized component models. Using more accurate models in Multisim would enhance accuracy.

4 Conclusion

Overall, the experiment successfully demonstrated the behavior of a series RC circuit under AC excitation. The relationships between voltage, current, impedance, and frequency were verified through both physical measurements and simulations. The understanding gained will aid in future circuit design and analysis involving RC components and AC signals.