LAB 8: RC CIRCUITS

Equipment List:

Dual Trace Oscilloscope
HP function generator
Breadboard
Assorted resistors and capacitors
1 BNC-to-banana
1 BNC-probe
Hand-held DMM
1 black banana lead

Theory: When a voltage is applied across a capacitor, the capacitor does not become fully charged immediately; when the voltage is first applied, the current that is charging the capacitor is large, but as the capacitor becomes more and more charged, the current decreases exponentially in time eventually coming to a zero value.

For resistors obeying Ohm's law, we know the voltage across a resistor increases as the current through the resistor increases linearly; things are different for a capacitor. As the current "through" a charging capacitor decreases, the voltage across the capacitor increases.

From Kirchhoff's Loop Law, the sum of the voltage across the resistor and the capacitor ($V_R + V_C$) is equal to the voltage of the source (the circuit forms one Kirchhoff loop. This is true at any instant of time whether the source voltage is AC or DC). As already stated, V_R is large when the current through the circuit is large; this means V_C must be small since the sum of V_R and V_C is a constant, V_{source}. As the capacitor charges up, the voltage across it will become large ($V_C = Q/C$). The current into the capacitor will decrease because of the Coulomb repulsion a charged capacitor plate has to the introduction of still more charge on itself. Since this is a series circuit, the current through the capacitor will be the same as that through the resistor ($I_R = I_C$). When the current gets smaller, V_R gets smaller, but its still always true that: $V_{\text{source}} = V_R + V_C$. You should examine the above argument until you appreciate the internal consistency of it.

Introduction: In this lab you will examine the effects of two different AC signals on a RC series circuit, a sinusoidal and a square signal. The discussion above applies to both cases of input signal forms.

Procedure:

1. Construct a circuit using the breadboard with a resistor and a capacitor in series. Connect the two terminals of the breadboard to the HP function generator using a BNC-to-banana cable.

2. The series RC circuit driven by a square signal: The square function can be thought of as an "on-off" switch; it has two and only two values. The result is that the capacitor is charging and then discharging at a frequency related to the frequency of the square

signal. The charging and discharging occur exponentially and the voltage across the capacitor will have an exponential curve throughout this process. Measure the voltage across the capacitor and observe this curve. Start at a period equal to about ten times RC. Increase the frequency of the signal and measure V_C. Explain what happens and why to the voltage across the capacitor as the frequency increases. If you were to pretend the capacitor was a resistor, would the capacitor act like a large resistor or a small resistor as the frequency increased (Hint: think about what happens to the current in the circuit)?

Graph V_C versus frequency. Make sure to check the value of the frequency from the oscilloscope, rather than just reading from the function generator. Graph the points while you take the data.

Note: Since your scope only measures the potential of a point in a circuit with respect to ground, you must make sure the other side of you capacitor is grounded. There is a ground terminal on the oscilloscope you can connect via a banana lead to your circuit. The scope probe should be placed between the capacitor and the resistor; if the other side of the capacitor is grounded, the scope will measure V_C.

3. The RC series circuit driven by a sinusoidal signal: Change the driving signal on the function generator from square to sinusoid. Set the frequency back to the original $10RC$. Increase the frequency and measure V_C as a function of the frequency, as in the previous part. Plot this data also. Explain what you observe.

Analysis: Comment on the accuracy of the function generator's reading of the frequency, as compared with what you observe on the oscilloscope screen. Is there a systematic error (offset) in your function generator? Comment on any problems you had taking data or any improvements that could be made to the methodology of this lab. Comment on any other errors that could contribute to noise in your data. Describe the shape of your graphs of frequency against potential difference. Are they similar?

Conclusion: What happens to the potential difference across the capacitor as the frequency increases? What must be happening to the potential difference across the resistor as the frequency increases? How could you change your circuit so that this behavior happened at a higher frequency? At a lower frequency? Can you think of any uses for this type of circuit? (Hint: this is a type of "low-pass filter".)