6.3.1: Capacitor Voltage-current Relations

Overview:

In this assignment, we will measure the relationship between the voltage difference across a capacitor and the current passing through it. We will apply several types of time-varying signals to a series combination of a resistor and a capacitor. The voltage difference across the resistor, in conjunction with Ohm's law, will provide an estimate of the current through the capacitor. This current can be related to the voltage difference across the capacitor.

The results of our voltage-current measurements will be compared to analytical expectations.

Before beginning this lab, you should be able to:

- State voltage-current relationships for capacitors in both differential and integral form
- Apply the capacitor voltage-current relations to calculate a capacitor's voltage from its current and vice-versa
- Use the Analog Discovery's arbitrary waveform generator and oscilloscope to apply and measure time-varying waveforms (Lab 6.2.1)

After completing this lab, you should be able to:

- Use the Analog Discovery oscilloscope's math function to calculate the current through a known resistor from the measured voltage difference.
- Verify a capacitor's voltage-current relations using measured data

This lab exercise requires:

- Analog Discovery module
- Digilent Analog Parts Kit

Symbol Key:

DEMO Demonstrate circuit operation to teaching assistant; teaching assistant should initial lab notebook and grade sheet, indicating that circuit operation is acceptable.

ANALYSIS Analysis; include principle results of analysis in laboratory report.

SIM Numerical simulation (using PSPICE or MATLAB as indicated); include results of MATLAB numerical analysis and/or simulation in laboratory report.

DATA Record data in your lab notebook.

General Discussion:

We will use the circuit of Figure 1 in this lab assignment. Both the voltage difference across the capacitor and the resistor ($v_C(t)$ and $v_R(t)$) will be measured. From this data, we can readily compare the voltage across the capacitor with the current through the capacitor. Since the voltage across the resistor is measured, we can readily infer the current through the resistor via Ohm's law:

$$i_R(t) = \frac{v_R(t)}{R} \tag{1}$$

The resistor and capacitor are in series, so the current through the capacitor is the same as the current through the resistor, so:

$$i_C(t) = \frac{v_R(t)}{R} \tag{2}$$

Since we are also measuring the voltage difference across the capacitor, $v_C(t)$, we can readily compare these parameters with our expectations based on our mathematical models of the capacitor voltage-current relationships.

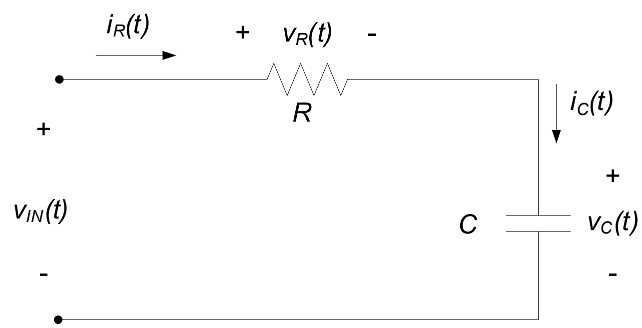


Figure 1. Series RC circuit.

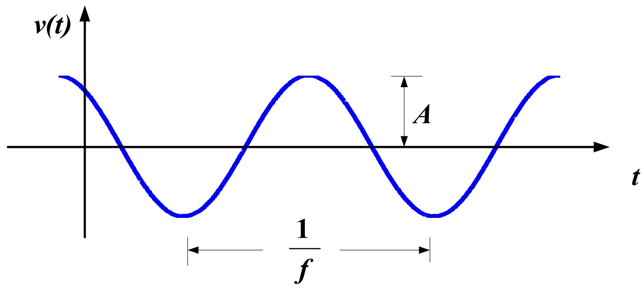
Pre-lab:

For the circuit of Figure 1, use the inductor voltage-current relations to overlay sketches of the capacitor voltage and the capacitor current ($v_C(t)$ and $i_C(t)$) if the capacitor voltage is:

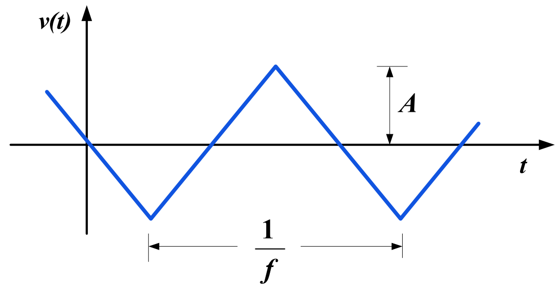
ANALYSIS (a) A sinusoidal wave, $v(t)$, with frequency (f) and amplitude (A) as shown in Figure 2 (a)

ANALYSIS (b) A triangular wave, $v(t)$, with frequency (f) and amplitude (A) as shown in Figure 2 (b).

Label your sketch to show the amplitude and period of the capacitor current for both of the above cases. Your results may be dependent up on the parameters A, f, R, and C. Be sure that your sketches of voltage and current share the same time axis!



1. *Sinusoidal waveform*



(b) Triangular waveform

Lab Procedures:

Construct the circuit of Figure 1, using R = 100Ω and C = 1μF. Use channel 1 of your oscilloscope to measure the resistor voltage difference, and channel 2 of your oscilloscope to measure the capacitor voltage difference. Use channel 1 of your waveform generator (W1) to apply the voltage $v_{in}(t)$ in Figure 1. Set up a math channel to calculate the current through the capacitor per equation (2) in the pre-lab[1]. Set the oscilloscope measurements to provide at least the amplitude of each of the three displayed waveforms.

1. Apply a sinusoidal input voltage with frequency = 1kHz, amplitude = 2V, and offset = 0V to the circuit of Figure 1. Use your oscilloscope to display the data listed above (waveforms corresponding to C1, C2, and M1; measurement window displaying amplitudes of C1, C2, and M1). Record the image of the oscilloscope window, showing the waveforms and their measured amplitudes. **DATA**
2. Apply a sinusoidal input voltage with frequency = 2 kHz, amplitude = 2V, and offset = 0V to the circuit of Figure 1. Use your oscilloscope to display the data listed above (waveforms corresponding to C1, C2, and M1; measurement window displaying amplitudes of C1, C2, and M1). Record the image of the oscilloscope window, showing the waveforms and their measured amplitudes. **DATA**
3. Apply a triangular input voltage with frequency = 100 Hz, amplitude = 4V, and offset = 0V to the circuit of Figure 1. Use your oscilloscope to display the data listed above (waveforms corresponding to C1, C2, and M1; measurement window displaying amplitudes of C1, C2, and M1). Record the image of the oscilloscope window, showing the waveforms and their measured amplitudes. **DATA**
4. Demonstrate operation of your circuit to the Teaching Assistant. Have the TA initial the appropriate page(s) of your lab notebook and the lab checklist. **DEMO**

[1] Detailed instructions for doing this are provided in Appendix A.

Post-lab Exercises:

ANALYSIS

For the three cases in the lab procedures (1kHz sinusoid, 2kHz sinusoid, 100Hz triangular wave), use your pre-lab results to sketch the expected capacitor current waveforms corresponding to the capacitor voltage waveforms you measured in the lab procedures. Comment briefly on the agreement between the measured and expected capacitor currents for each of these cases. In your comments, be sure to include a quantitative comparison (including percent difference) between the expected and measured amplitudes of the capacitor current.