

Name: _____

Hands-on Introduction to Electrical Engineering

Assignment 4: Capacitors and Inductors

1 Topics

In this assignment, you will review the following topics:

- Step-signal inputs to capacitive and inductive circuits,
- Sinusoidal inputs to capacitive circuits,
- Simple applications of capacitors

Please make sure that you are familiar with these topics prior to the lab session. In addition, you will make independent use of the oscilloscope and the function generator.

2 Step responses of capacitive and inductive circuits

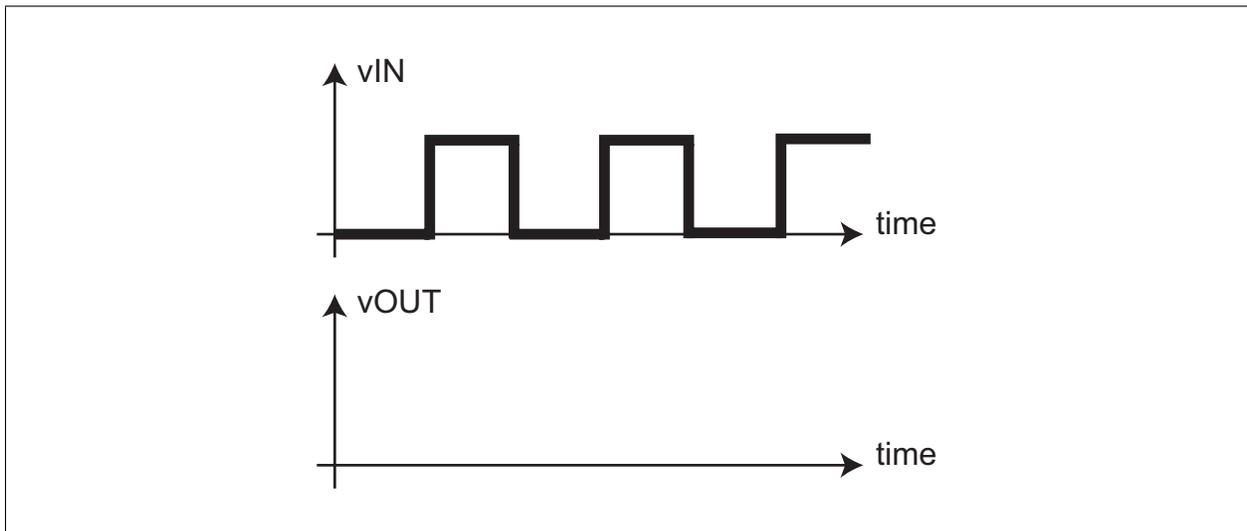
2.1 Predict the output

Consider the simple R - C and L - R circuits as shown in Fig. 1. For each circuit, predict the output waveform corresponding to a square wave input.

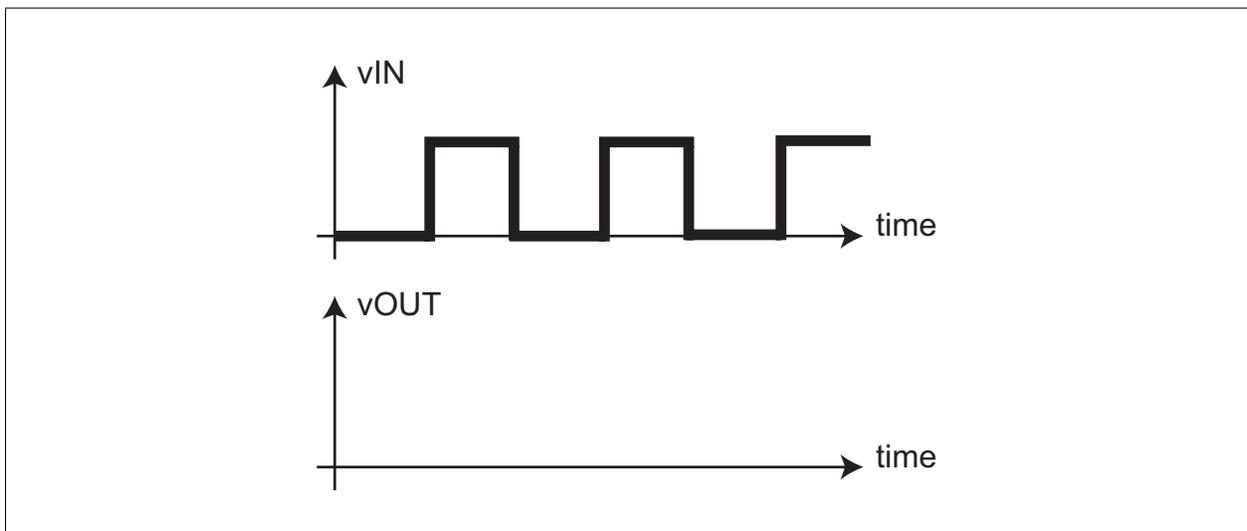


Figure 1: Basic RC and LR circuits. We use $R = 1 \text{ k}\Omega$, $C = 0.47 \mu\text{F}$, $L = 33 \text{ mH}$.

For the RC circuit:



For the LR circuit:



What are the theoretical time constants of each circuit?

$$\tau_{RC} =$$

$$\tau_{LR} =$$

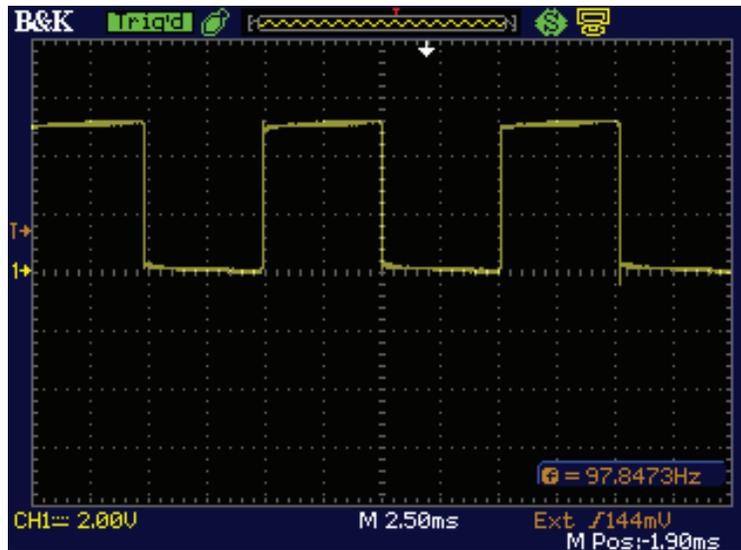


Figure 2: Desired square wave input, at frequency $f = 100$ Hz and switching between 0 and 5 V.

2.2 Set up the square wave input

Use the function generator and the oscilloscope to set up a $f = 100$ Hz square wave that has a low value of 0 V and a high value of 5 V. The desired waveform is illustrated in Fig. 2.

2.3 Measure the response

For the RC and LR circuits of Fig. 1, observe the output waveform when the input is a square wave. Using the MEASURE function of the oscilloscope, experimentally find the time constant of each circuit.

$$\tau_{RC, \text{expt}} =$$

$$\tau_{LR, \text{expt}} =$$

3 Sinusoidal response of capacitive circuits

We will now drive the RC circuit with a sinusoidal input, rather than a step input. Please use the function generator to produce the signal

$$v_{\text{IN}}(t) = 2.5 \text{ V} + 1.0 \text{ V} \cdot \sin(2\pi ft)$$

where t is time and f is the frequency of the sinusoid (which will be varied throughout this exercise).

Sweep the frequency from $f = 100 \text{ Hz}$ to $f = 10 \text{ kHz}$. How does the gain $v_{\text{out}}/v_{\text{in}}$ change as function of f ?

frequency	gain
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You should have found that the circuit gain is dependent on the frequency. Can you think of an application of the frequency-dependent gain?

In addition to the frequency-dependent gain, you should also observe that the relative **phase** between the input and output sinusoids changes as a function of frequency. Describe your observation.

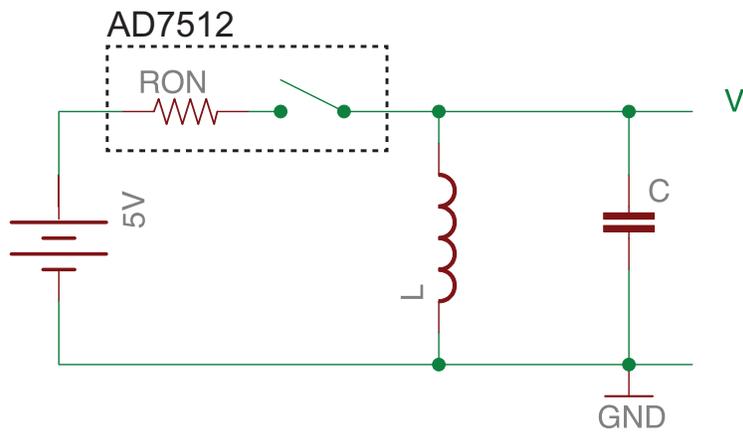


Figure 3: An LC circuit which can be charged by a switch.

4 Circuits involving both L and C

When a circuit contains both an inductive and a capacitive element, the circuit may oscillate. For the LC circuit of Fig. 3, the frequency of oscillation is given by

$$f_{LC} = \frac{1}{2\pi\sqrt{LC}}.$$

We will use the AD7512 “analog switch” as an electronic switch that will initially drive the LC circuit (specifically, the inductor).

Use the AD7512 datasheet to implement the switch, and construct the LC circuit as shown in Fig. 3. Measure the frequency of oscillation and record it below:

$f_{LC, \text{expt}} =$

You should find that the amplitude of the oscillation decays over time. What do you think this implies about the LC circuit that you constructed?

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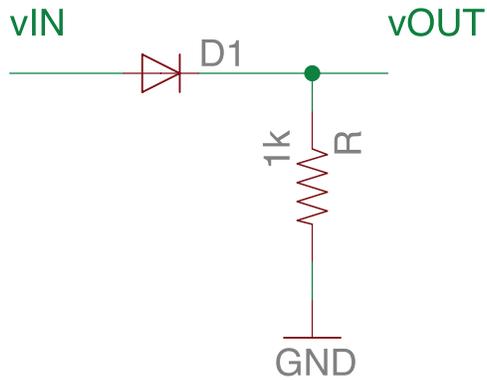


Figure 4: Half-wave rectifier circuit.

5 Applications of capacitors

This section shows a few simple applications of capacitors, which make use of the fact that capacitors oppose sudden changes in voltage across its terminals (*i.e.* it “low-passes” the voltage signal).

5.1 Half-wave rectifier

Set up the function generator output to a 5 V amplitude sinusoid with no DC bias. A diode can be used to “rectify” this AC signal to produce a DC output.

Build the half-wave rectifier as shown in Fig. 4. Observe the input and the output. Why do you think the circuit is called a “half”-wave rectifier?

Now add a capacitor parallel to the resistor in Fig. 4. Try (among others) $C = 1 \mu\text{F}$ and $C = 100 \mu\text{F}$. Be careful to note the polarity of electrolytic capacitors! How does the output change when a capacitor is added? Draw example output waveforms.

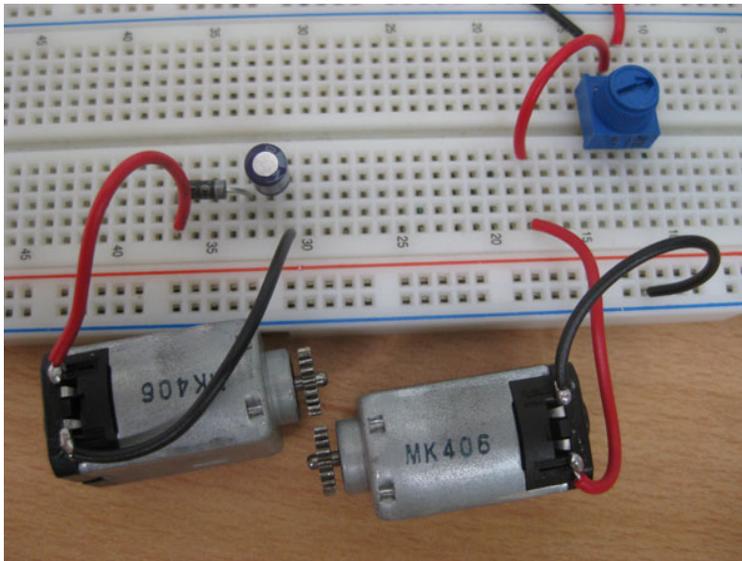


Figure 5: When forcibly driven by the motor on the right, the “generator” motor on the left will produce an output voltage at its terminals.

5.2 Power generation

As you may already know, electricity can be generated when a loop of wire is rotated in the vicinity of a static magnetic field. (This effect was discovered by Ampere.) A DC motor has exactly the configuration of wire loop and magnet, and thus can be used to generate electricity when the motor is forcibly turned.

As in Fig. 5, you will be shown a “generator” motor that is driven by another motor. In general, the generator can be driven by flow of water (hydroelectric generator), flow of wind (wind power), or from a heat source through the application of a heat engine (*e.g.* Stirling engine). Compare the generator voltage directly at the output (before the diode) and at the capacitor.

5.3 Switch debouncing

When mechanical components are used to provide electrical signals (such as the pushbutton switches of Assignment 2), the waveform often suffers from “jumpiness” which will be demonstrated. How can you use an RC circuit to overcome this problem?