EE-241. Introductory Electronics Laboratory
Lab 7 Handout*
LC circuits, resonance and transformers

Fall 2009

Objectives

At the end of this lab you should know

- Resonance in LC circuits.
- Frequency response of LC circuits and bandpass filtering.
- Transformers and how they can be used to induce voltage into an LC circuit.
- Basic principle of an AM radio.

Theory

Background section in Experiment 8 of Y. Tsividis *pg*. 62 - 66.

Prelab Problems

Consider an LC circuit as shown in Fig. 1 (page 62) with a switch between capacitor and inductor. Assume the circuit resistance and electromagnetic radiation is negligible. Also the initial charge on the capacitor is Q_{max}. If the switch is closed at time t = 0, answer the following questions.

1. Quantitatively explain the variation in energy on capacitor and inductor during equal intervals of time $t = \frac{T}{4}$. Where T is the period of oscillation. *Hint: the oscillations in LC circuit are electromagnetic analog to the mechanical (simple harmonic) oscillations of a block of mass m attached to a spring.*

2. Derive an expression for angular resonance frequency ($\omega_{resonance}$), current in the circuit (I) and charge on the capacitor (Q).

   (a) How does the charge on the capacitor and current in the circuit vary with time? Draw their waveforms. Clearly show the peak values of the two quantities.

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(b) Show that current is 90 degrees out of phase with the charge and the amplitudes of energy stored in inductor and capacitor are equal.

(c) Note that at some instances of time, the charge on the capacitor is zero but at such instances of time the current is not zero. How is it possible?

Hint: you can start by considering charge on the capacitor and current in the circuit at arbitrary point in time when $Q < Q_{max}$ *and* $I < I_{max}$. *Also note that at any point in time, the total energy stored in the circuit is equal to total initial energy stored in the capacitor at time* $t < 0$. *Moreover, total energy in the system is always conserved.*

3. Derive an expression for the total energy in an LC circuit. Show that it is equal to the initial energy stored in the capacitor before time $t = 0$. *Hint: note that the max energy stored in the inductor (when* $Q = 0$*) is equal to the initial energy stored in the capacitor (when* $I = 0$*).*

Now let us make our circuit more realistic by adding a resistance R (representing a finite resistance in the LC circuit) in series with the inductor and capacitor. This is called a RLC circuit (analogous to damped oscillator). Assuming the electromagnetic radiation in the circuit is still negligible and the capacitor is initially charged to Q_{max}. If the switch is closed at time t = 0, answer the following questions.

4. Derive an expression for charge in a RLC circuit. Draw its waveform.

5. Give the condition for under-damped, critically-damped and over-damped oscillations in the system. How can you tell when a RLC circuit is overdamped or underdamped? What is the significance of critical damping in RLC circuit?

6. Show how charge varies with time in an over-damped RLC circuit. Show peak values of the waveform.