

ECE-311 (ECE, NDSU)
Lab 9 – Simulation
Series and parallel resonance 1: LTSpice simulation

1. Objective

The response of a circuit containing both inductors and capacitors in series or in parallel depends on the frequency of the driving voltage or current. This lab and the next will explore one of the more dramatic effects of the interplay of capacitance and inductance, namely, resonance, when the inductive and capacitive reactances cancel each other. Resonance is the fundamental principle upon which most filters are based.

The objective of this lab is to use simulation (in the next lab you will conduct experiments) to:

- Study the behavior of series and parallel LC circuits at resonance.
- Understand the resonance frequency, cut-off frequency, bandwidth and quality factor of a resonance circuit.
- Determine if a circuit is inductive or capacitive and to understand the circuit behavior at resonance.

2. Introduction

Resonant circuits form the basis for filters that have better performance than first order (RL, RC) filters in passing desired signal or rejecting undesired signals that are relatively close in frequency. The resonance frequency is defined as the frequency at which the impedance of the circuit is purely real, that is, with zero reactance. For the reactance to be zero, impedance of the inductor must equal that of the capacitor. At resonance, the impedance of a branch with LC in series is equal to zero, which is equivalent to a short, and the admittance of a branch with LC in parallel is equal to zero, which is equivalent to an open. As the frequency increases, the magnitude of an inductive reactance increases, while the magnitude of a capacitive reactance decreases. A circuit is said to be inductive if the total reactance is positive, and a circuit is said to be capacitive if the total reactance is negative.

A bandpass RLC circuit will have two cut-off frequencies ω_{c2} and ω_{c1} where the amplitude is $1/\sqrt{2}$ of the maximum value. The cut-off frequency is also called the half-power frequency or 3-dB frequency in some cases.

The bandwidth (denoted as $BW = f_{c2} - f_{c1}$ or $\beta = \omega_{c2} - \omega_{c1}$) is defined as the difference between the upper and lower cutoff frequencies. In case of a low-pass filter or baseband signal, the bandwidth is equal to its upper cutoff frequency.

Examples of the resonance frequency, cutoff frequencies and the bandwidth are shown in Figure 1 for a bandpass and a bandreject filter.

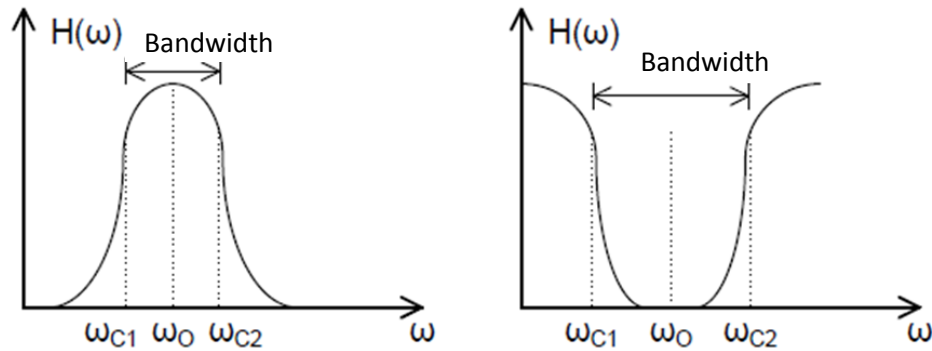


Figure 1: Resonance frequency, cutoff frequencies, and bandwidth

The quality factor or Q factor of the frequency response is described quantitatively in terms of the ratio of the resonance frequency to the bandwidth:

$$Q = \omega_0 / \beta$$

with both ω_0 and β in radians. This definition lends itself to laboratory measurement because it is possible to measure both the resonance frequency (ω_0) and the bandwidth (β). It is also defined as an energy ratio:

$$Q = 2\pi \frac{\text{maximum energy stored}}{\text{total energy lost per period}}$$

The steady response of a circuit will in general have a maximum amplitude and a phase angle that is different from that of the source. In some cases, the magnitude of the voltage response may exceed that of the voltage source.

3. Preparation

(1) RLC circuit basic measurement

For circuits (a) through (d) in Figure 2, use $C = 0.1 \mu\text{F}$, $L = 100 \text{ mH}$, and $R = 1 \text{ k}\Omega$.

- Derive the transfer function.
- Find the resonance frequency, cutoff frequencies, bandwidth and Q factor for each circuit.
- What is the phase relation between the total voltage and current, is it leading or lagging when the frequency is (i.) below resonance, and (ii.) above resonance? What is the nature of the circuit in those two regions (i.e., is it capacitive or inductive)?

(2) RLC circuit at resonance

For circuit (e) in Figure 2, use $C = 0.1 \mu\text{F}$ and $L = 100 \text{ mH}$.

- At resonance frequency, calculate V_C if:
 - $R = 3 \text{ k}\Omega$
 - $R = 300 \Omega$
- Find out whether the magnitude of V_C is larger or smaller than V_{in} . Explain your result.

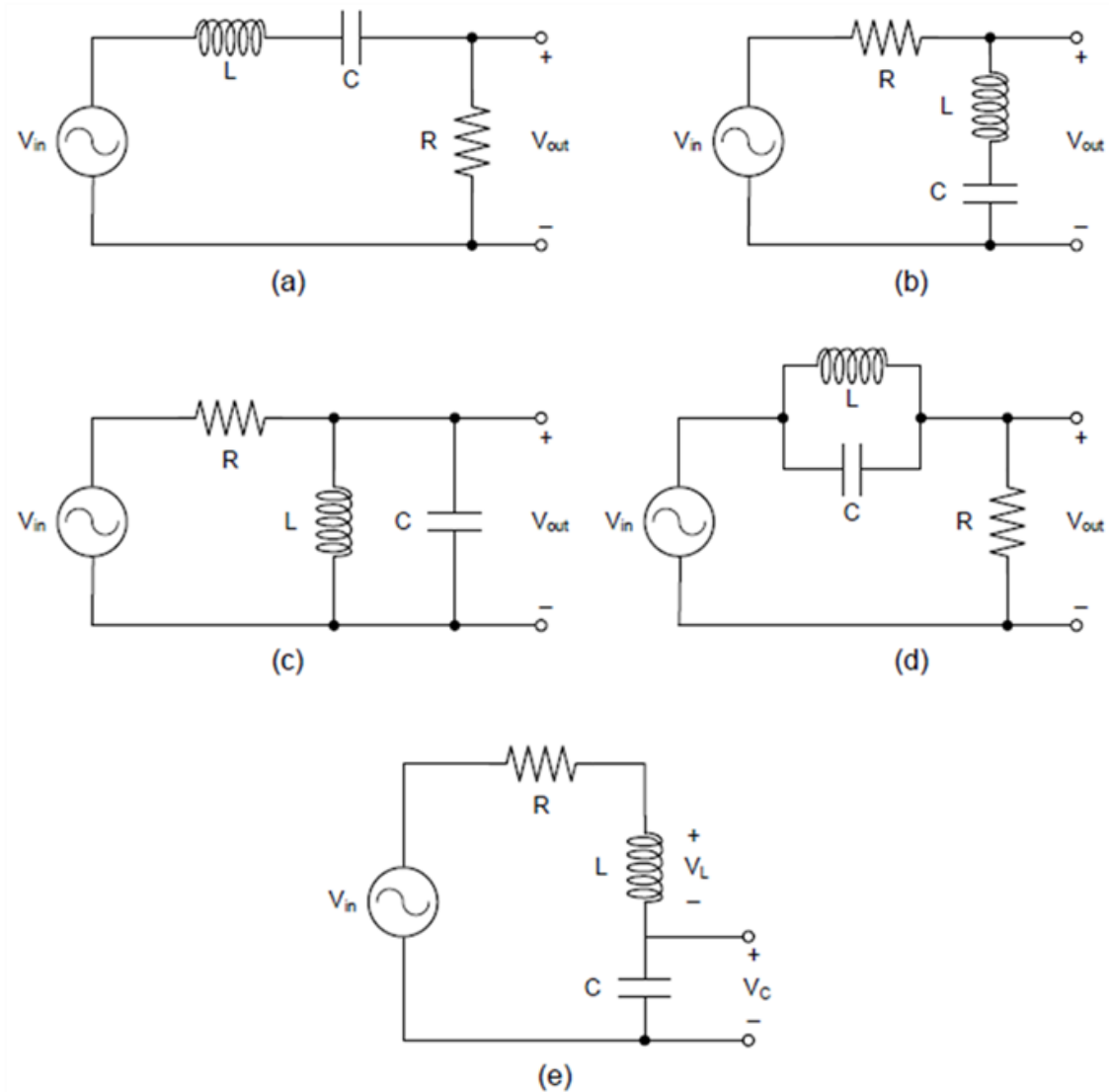


Figure 2: Circuits

4. Simulation

- (1) Build and simulate the circuits (a) through (d) in Figure 2 using LTSpice. Find the resonance frequency, half-power frequencies bandwidth, and Q factor for each circuit. Compare the result with that from Preparation.
- (2) Build and simulate the circuit (e) in Figure 2. Find the magnitude for V_C for the following cases:
 - i. $R = 3 \text{ k}\Omega$
 - ii. $R = 300 \Omega$

Compare the result with that from Preparation.