EE 3101 ELECTRONICS I LABORATORY

EXPERIMENT 1 LAB MANUAL

RESONANT CIRCUITS

OBJECTIVES

In this experiment you will
- Learn how resonant circuits can be used to make band-pass and band-reject filters.
- Gain experience in measuring the frequency response of a simple network.
- Become familiar with the laboratory layout and equipment.

LAB NOTEBOOKS

The format of lab notebooks should be such that the information can be used to reproduce the lab, including what values were used in a circuit, why the values were used, how the values were determined, and any results and observations made. This lab manual will be used as a guide for what calculations need to be made, what values need to be recorded, and various other questions. The lab notebook does not need to repeat everything from the manual verbatim, but it does need to include enough information for a 3rd party to be able to use the notebook to obtain the same observations and answers. In the following numbered sections there are **bolded words and/or lines**. These bolded words and/or lines are statements and/or questions that the lab TA will be looking for an answer either in the lab preliminary, or lab notebook.

INTRODUCTION

Figure 1 shows two simple models for a practical inductor. The model in Figure 1(a) is used for when the effective series resistance is critical to the intended use of the inductor, and the model in Figure 1(b) is used when the effective parallel resistance is critical.
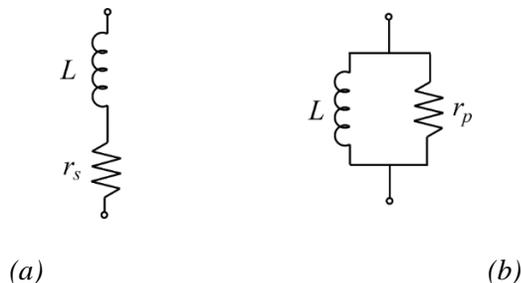

(a)   *(b)*

Figure 1: Two ways of modeling a practical inductor.

Resistances r_s and r_p represent the losses in a real inductor or coil in regard to the Quality factor of the inductor. Note that the value r_s is not the same as the dc resistance of a coil. The Quality factor can be defined as

$$Q = 2\pi \frac{peak\ energy\ stored\ in\ the\ circuit}{energy\ dissipated\ by\ the\ circuit\ in\ one\ period} \qquad (1)$$

It can be shown for a series circuit, such as Figure 1(a), that Q can be expressed as $\frac{|X|}{R}$, where X is the reactance given by ωL, or $\frac{1}{\omega C}$ for a capacitive circuit, and R is the resistance. It can also be shown that for a parallel circuit, such as Figure 1(b), that Q can be expressed as $\frac{R}{|X|}$, [1]. The question now is how to obtain these resistance values from the manufacturers' data.

The inductor we will use in this experiment has the following specifications:

Inductance [μH]	Q [min]	Test Frequency [kHz]	SRF [MHz]	DCR [Ω]	IDC [mA]
220 ±10%	60	796	4.0	7.0	130

In this case, we have a coil with an inductance of 220 μH with ± 10% tolerance. When measured at a test frequency of 796 kHz, the coil Q is guaranteed to be at least 60. This means that if the coil is resonated at 796 kHz with an ideal capacitor, it will exhibit an effective quality factor of $Q_c \geq 60$. Due to the distributed capacitance of the winding, the coil will exhibit a self-resonance point at f = 4 MHz. Inductors are typically used at frequencies much lower than the self-resonant frequency (SRF). The maximum dc resistance is 7 Ω and any dc current flowing through the inductor must be limited to 130 mA.

PRELIMINARY

1. **Calculate the values of r_s and r_p** using the equations from the introduction, for the 220 μH inductor.

2. For any simple resonant circuit with two energy storage elements, whether series or parallel connected, it can be shown that the resonant frequency can be calculated by

$$f_c = \frac{1}{2\pi\sqrt{LC}},$$

where f_c, L, and C are the center or resonant frequency, the circuit inductance, and the circuit capacitance, respectively.

3. **Calculate the capacitance C** needed for a resonant frequency of 400 kHz for the given inductor (220 μH).

EXPERIMENT

Part A: Series Resonant Band Pass Filter

The series-resonant circuit shown in the left hand side of Figure 2 is configured to perform a band-pass function. That is, at resonance, the reactance of C will cancel the reactance of L, leaving only a resistive circuit. This will provide maximum coupling at the resonant frequency, f_c. A band-pass filter will have a frequency response similar to that shown at the right hand side of Figure 2. From the frequency response it can be seen that the band width, BW, is determined by the -3dB points, or the frequencies where the amplitude of the output is down by 3dB from the amplitude at resonance.
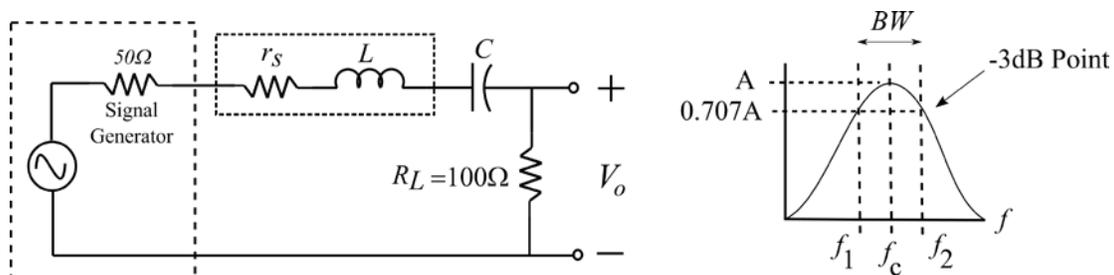

Figure 2: Band-pass filter.

4. Calculate the **loaded Quality factor**, Q_L, of the circuit at f_c. Loaded quality factor refers to the fact that the load resistance R_L will affect the quality factor.

5. **Calculate the bandwidth of the filter**, where

$$BW = \frac{f_c}{Q_L}$$

Using a breadboard and parts in the lab, construct the circuit of Figure 2. You may have to use a combination of capacitors to get the required value of C. Set the signal generator output to approximately 1 Vp-p. Use an oscilloscope probe to connect the output of the circuit to the oscilloscope. Adjust the signal generator frequency to find the center (resonant) frequency f_c. The resonant frequency will be the frequency at which the largest signal level will be observed on the oscilloscope display (V_{max}).

6. **Tabulate this value in Table 1**.

Table 1.

Frequency	V_{p-p}
f_1, -3dB freq.:	
f_c:	
f_2, -3dB freq.:	

7. Adjust the signal amplitude for full scale (8 divisions) on the oscilloscope at the circuit output, then vary the signal generator frequency above and below f_c to obtain the –3dB points. At these two cutoff frequencies f_1 and f_2 the output voltage drops to around 70% of its maximum values ($0.707\ V_{max}$).

8. **Tabulate these values in Table 1**.

9. **Obtain enough frequency points to fill out Table 1.**

10. **Plot a sketch of amplitude vs frequency (The frequency response of the circuit).**

11. **Determine the bandwidth of this filter.**

Q1.   **How does the measured resonant frequency and bandwidth compare with those calculated?**

Q2.   **What factors could have contributed to any differences?**

Part B: Series Resonant Band Reject Filter

The series-resonant circuit shown in the left hand side of Figure 3 is configured to perform a band-reject function. That is, at resonance, the reactance of C will cancel the reactance of L, leaving only a resistive circuit. This will provide maximum coupling at the resonant frequency, f_c. A band-reject filter will have a frequency response similar to that shown at the right hand side of Figure 3. From the frequency response it can be seen that the band width, BW, is determined by the -3dB points, or the frequencies where the amplitude of the output is down by 3dB from the

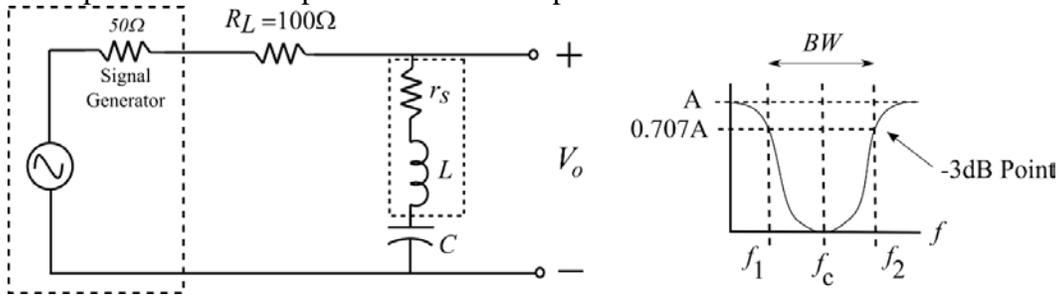maximum amplitude of the output observed in the pass band of the filter.

Figure 3: Band-reject filter.

1. Reconfigure the circuit to make a band-reject filter of Figure 3. Set the signal frequency to approximately 20 kHz, and set the oscilloscope volt/division so that the circuit's output waveform fills the oscilloscope display area. Slowly increase the frequency to determine the center (resonant) frequency. The resonant frequency will be the frequency at which the smallest signal level will be observed on the oscilloscope display. Vary the frequency above and below the resonant frequency.

2. **Record data such as outlined in Table 2**.

3. **Plot a sketch of amplitude vs frequency (The frequency response) for the filter**.

4. **Determine the bandwidth of this filter**.

Table 2.

Frequency	V_{p-p}
f_1, -3dB freq.:	
f_c:	
f_2, -3dB freq.:	

Part C: Parallel Resonant Band Pass Filter

1. Construct a band-pass filter using a parallel-resonant circuit as shown in Figure 4. Use the same L and C values.
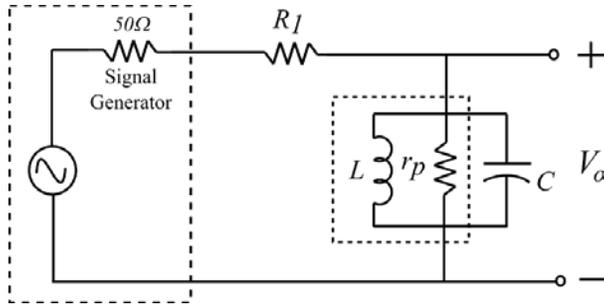
Fig. 4. A parallel-resonant circuit configured as a band-pass filter.

2. **Calculate the required circuit Q for a bandwidth of 50 kHz.**

3. **Calculate the required parallel resistance R to obtain this Q.**

Q3. **What value is needed for R_1 to obtain this equivalent R?** *(Hint: What is the equation for R when Norton's theorem is applied to the source?)*

4. **Determine the center (resonant) frequency and –3dB points, and fill out Table 3.**

5. **Plot a sketch of amplitude vs frequency.**

Table 3.

Frequency	$V_{p\text{-}p}$
f_1, -3dB freq.:	
f_c:	
f_2, -3dB freq.:	

Q4. **How do these measured frequencies compare with your desired design frequencies?**

Q5. **What would happen if you interchanged the parallel resonant circuit and R_1?**

[1] Cunningham, D. Stuller, J. 1991. Basic Circuit Analysis. Boston, Massachusetts. Houghton

Mifflin Company.