EE 255
ELECTRONICS I LABORATORY
EXPERIMENT 1
RESONANT CIRCUITS

OBJECTIVES

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

INTRODUCTION

Before proceeding with the electronics experiments, we will briefly explore simple series- and parallel-resonant circuits. As you know, resonance is an important phenomenon in many fields. Resonant circuits are used extensively in communication and wireless circuits, energy and power electronics circuits, audio and video equipment, and other circuits. Read through this experiment *before class* and prepare as much as you can before your lab session. This will make things go quickly and smoothly. You may also want to refer to your circuits textbook. This material is not in the 253 text.

INTERPRETING INDUCTOR SPECIFICATIONS

Figure 1 shows two simple models for a practical inductor. The model in Fig. 1(a) is used for series-resonant cases, while the model in Fig. 1(b) is used for parallel-resonant cases.
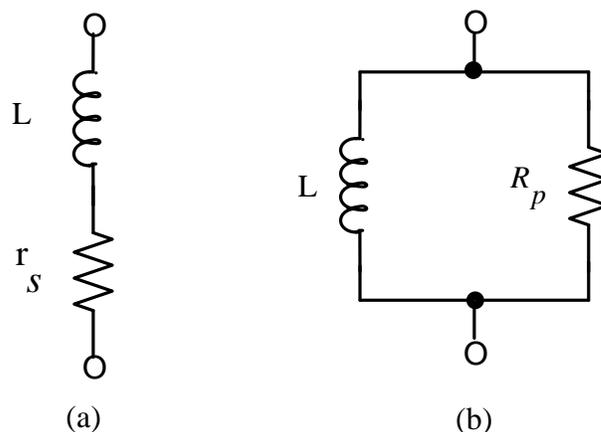

(a)   (b)

Fig. 1. Two ways of modeling a practical inductor.

Resistances r_s and R_p represent the losses in a real inductor (coil). Note that the value r_s is not the same as the dc resistance of coil. The question now is how can we obtain these resistance values from the manufacturers' data.

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

Inductance	Qmin	Test Freq.	Min. SRF	Max. DC Res.	Max. DC Current
220µH ± 10%	30	0.79 MHz	9 MHz	21 Ω	52 mA

In this case, we have a coil with an inductance of $220\,\mu H$ with $\pm$ 10% tolerance. When measured at a test frequency of 790 kHz, the *coil Q* is guaranteed to be at least 30. This means that if the coil is resonated at 790 kHz with an ideal capacitor, it will exhibit an effective quality factor of $Q_c \geq 30$. Due to the distributed capacitance of the winding, the coil will exhibit a self-resonance point at f = 9 MHz. We usually want to use the inductor at a frequency << this self-resonant frequency (SRF). The maximum dc resistance is 21 ohms and any dc current flowing through the inductor must be limited to 52 mA.

We can obtain the value of r_s by noting that the coil Q is defined as

$$Q_c = \omega L/r_s \quad \text{so that} \quad r_s = \omega L/Q_c$$

If Q_c is high, it can be shown by equating the two networks of Fig. 1 that R_p can be approximated as

$$R_p = r_s\,Q_c^{2} = \omega L Q_c$$

Thus, given the test frequency in the data sheet, we can calculate estimates of loss resistances r_s and . R_p

EXPERIMENT

1. Using the equations given above, calculate the values of r_s and R_p for the $220\,\mu H$ inductor.

2. The series-resonant circuit in Fig. 2 is configured to perform a bandpass 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 f_o. Calculate the capacitance C needed for a resonant frequency f_o of 400 kHz.
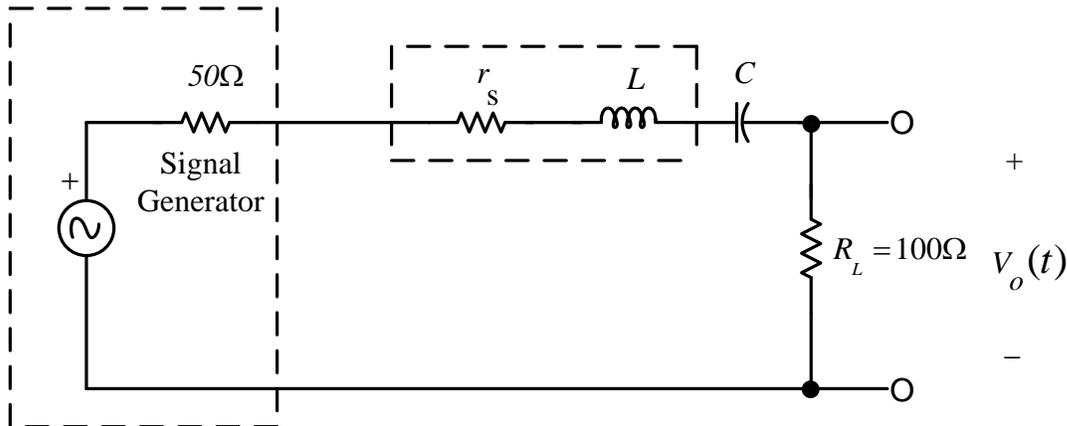
Fig. 2. A simple LC bandpass filter.

3. Calculate the *loaded Q* of the circuit at f_o:

$$Q_L = \omega_o L / R \quad \text{where R is the effective series resistance in the circuit.}$$

4. Calculate the bandwidth of the filter:
$$BW = f_o / Q_L$$

5. Using a breadboard and parts in the lab, construct the circuit of Fig. 2. You may have to use a combination of capacitors to get the required value of C.

6. Set the signal generator output to about 1 volt peak-to-peak. With the your oscilloscope probe connected to the output, adjust the signal frequency to find the center (resonant) frequency f_o. Note this value. Adjust the signal amplitude for full scale (8 divisions) on the scope at the circuit output, then vary the frequency above and below f_o to obtain the –3dB (i.e., the 0.707) points. How does your measured center frequency and bandwidth compare with those calculated above? What factors could have contributed to the differences?

7. Next, reconfigure the circuit to make a band-reject filter of Fig. 3. Set the signal frequency at least 20 times greater or 20 times less than f_o and set the amplitude of the circuit's output to full scale on the scope. Vary the frequency to determine the center (resonant) point. Now, vary the frequency above and below f_o, taking amplitude data. Plot a sketch of amplitude vs frequency. Determine the bandwidth of this filter.
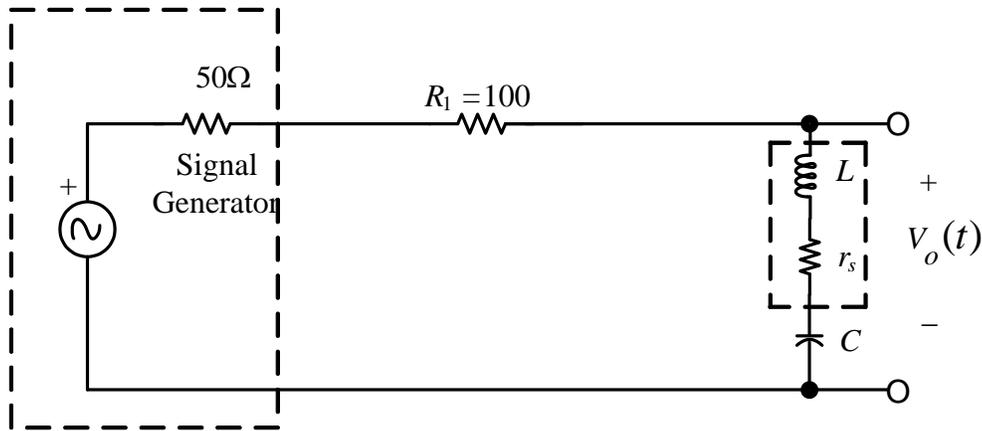
Fig. 3. A simple band - reject filter.

8. Next, we will construct a bandpass filter using a parallel-resonant circuit as shown in Fig. 4. Use the same L and C values. Calculate the required circuit Q for a bandwidth of 50 kHz:

$$Q_L = f_o/BW$$

Calculate the required parallel resistance R to obtain this Q:

$$R = \omega_o L Q_L$$

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?)

9. Construct the circuit and determine the center (resonant) frequency and –3dB points. How do these measured frequencies compare with your desired design frequencies? What would happen if you interchanged the parallel resonant circuit and R_1?
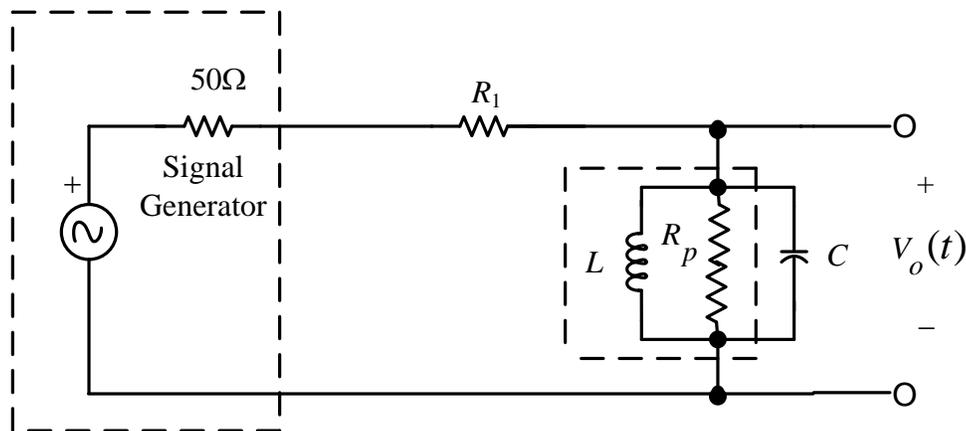

Fig. 4. A parallel-resonant circuit configured as a bandpass filter.

COMMENTARY

    Generally speaking, you will use series resonant circuits in low-impedance circuits and parallel resonant circuits in high-impedance circuits. This will make it possible to obtain a reasonable circuit Q and BW. The series-resonant circuit in Fig. 5(a) performs a bandpass function in the low-impedance input circuit of a common-base amplifier. The high-impedance input of the JFET amplifier of Fig. 5(b) prevents loading of the parallel resonant bandpass filter. If this filter had been connected to the input of a BJT, the effective resistance R would have been lowered, and the circuit Q would be low. This would result in a very broad bandwidth which may not be desired. Higher-order filters with more-ideal characteristics can also be designed. These are covered in other courses and reference books.
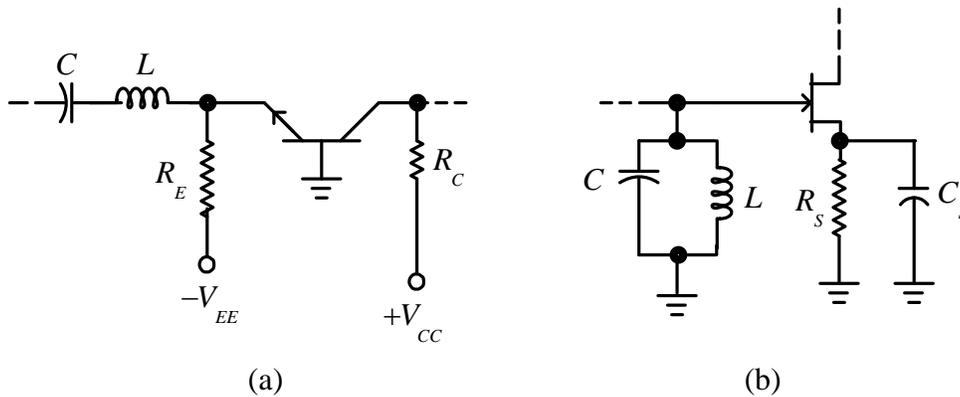

(a)   (b)

Fig. 5. Bandpass filters for low- and high-impedance level circuits.