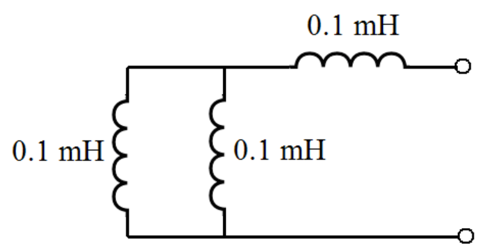
# Experiment 9
# Lab Activity

## Pre-Lab Activity

Read the Pre-reading materials, the laboratory activity and the post-lab before coming to the Laboratory. Solve the following problems and submit your solution to your instructor.

**Problems**

1. How many winding does a 1mH inductor have if the inductor's air core has a diameter of 5 cm and an effective length of 10cm?
2. Find the inductance and resistance for an inductor made out of 2 meters of Gauge #40 copper wire wound around an iron core of effective length $l$ = 1 cm and 0.5cm diameter.
3. A 0.1mH capacitor is used in a circuit and has $i_L(t) = 40\cos(500\pi t)$ mA. Determine the inductor's voltage, $v_L(t)$.
4. Find the equivalent inductance for the following network of inductors.




5. Consider the circuit in Figure 10. Assume $L$ = 1mH and $R$ = 680Ω. What is the value of $\tau$? What should the frequency of the square wave source be in order to clearly display the charge/discharge cycles of the inductor?
6. Assume $V_S$ = 4V for Problem 5. Use Multisim (and its virtual scope) to solve for and display the resistor's voltage. Employ the scope's cursors to measure the time constant. Now, write the expression for the charging cycle portion of the inductor current.
7. Repeat Problems 5 and 6 assuming $R$ = 47Ω; here, you must use the model in Figure 11. Assume $R_o$ = 10Ω, and $R_S$ = 50Ω.

8. Consider the circuit in Problem 7. Assume that the inductor is rated at 70mA maximum current and the resistor is rated at ½ Watt. Does the supply voltage amplitude $V_S$ = 4V meet the inductor and resistor ratings? Hint: The maximum current in the circuit is equal to $V_S/R_T$.
9. Consider the voltage integrator circuit in Figure 16. Assume $R$ = 470Ω, $L$ = 1mH and the op-amp saturation voltage is 14V. Let $v_{in}$ = $2\cos(2\pi ft)$. What is the lower limit on $f$ for the integrator to operate as a linear circuit?

## Laboratory Activity

Required components:

One 47Ω resistor (±5%, ½ W)

One 470Ω resistor (±5%, ½ W)

One 680Ω resistor (±5%, ½ W)

One 10kΩ resistor (±5%, ½ W)

One 1mH ferrite-cored inductor (±10%, 70mA max current)

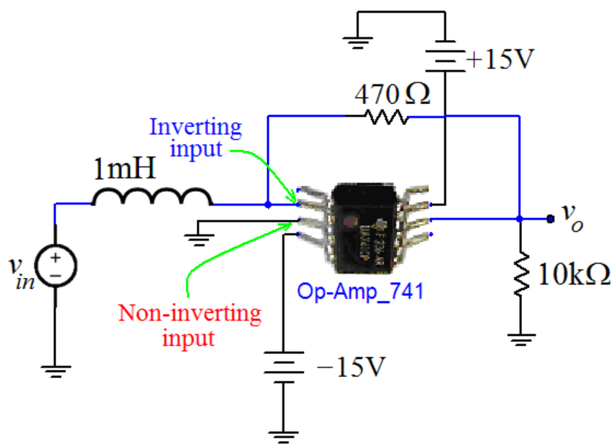
LM741 op-amp

Note:

- All circuits in this experiment (and in all future experiments) should be constructed on the protoboard.
- When making current measurements, set the ammeter to display the reading in mA. Record your measurement with two significant digits to the right of the decimal point (employ rounding).
- When making voltage measurements, set the voltmeter to display the reading in Volts. Record your measurement with two significant digits to the right of the decimal point (employ rounding).
- When measuring resistance, set the multimeter to record the displayed reading accurate to two significant digits to the right of the decimal point.

1. Obtain the above resistors from your lab instructor and measure and record their actual resistance. Also, measure and record the inductor's resistance $R_o$. In this experiment, assume that the function generator's internal resistance is $R_S = 50\Omega$.
2. Build the series *RL* circuit shown in Figure 10 using the 1mH inductor and the 680Ω resistor.
3. Use the measured value of *R* and the nominal value of *L* to compute the time constant $\tau$, taking into account the fact that $R > 10(R_o + R_S)$.
4. Set the function generator to generate the positive square voltage signal in Figure 9. Let $V_S = 4V$ and set the frequency to $1/(10\tau)$. Use the scope to verify the amplitude and frequency of the square signal. Note: You are going to need to use the *offset feature* of the function generator to generate the positive square signal. Also, calibrate the scope's probe if needed. Employ the scope's Quick Measure soft menu to measure the minimum and maximum values of the resistor's voltage.
5. Use the scope (apply autoscale) to display the input voltage and the resistor's voltage. Save the display as an image file.
6. Adjust the scope's horizontal and vertical gain so as to display the largest possible (stable) single discharge cycle. Save the display into an image file.
7. Employ the scope's cursors to measure the time constant, $\tau$. A convenient method for estimating $\tau$ is to use $\tau = 1.44t_{1/2}$, where $t_{1/2}$ is the time it takes a charge (or discharge) cycle to reach ½ of its peak-to-peak value.
8. Repeat Steps 2-7 using the 47Ω resistor. Since $R < 10(R_o + R_S)$, you must treat this circuit as one with a small *R* value. Here, the time constant is given by $\tau = L/(R + R_o + R_S)$.
9. Switch the position of the resistor and inductor. Use the scope to display and save the function generator voltage signal and the inductor's voltage signal. Measure the maximum and minimum values for the inductor's voltage.
10. Build the op-amp integrator circuit shown below. Let the input be a (zero-offset) sine wave with a 12kHz frequency. While the input voltage signal is connected to the integrator circuit, use the scope to set the peak-to-peak voltage to 4V. Display the input signal and

the output signal on the scope (apply averaging if the signals look noisy). Save the display as an image file. Measure the peak-to-peak value of the output voltage signal. Also, measure the time shift between the input and output sinusoidal signals.




11. Slowly decrease the frequency of the input signal by 100Hz increments until the integrator output is about to saturate. Stop and record this frequency.
12. Sort all components and give them back to your instructor.

## Post-Lab Activity

Write a technical report that discusses your observations and includes analysis and justifications of all steps in this activity. Tabulate and/or plot experimental data whenever possible. More specifically, your report should address the following points:

Note:

- Use the actual (measured) resistor values in all theoretical calculations and in Multisim simulations.
- When you are asked to "compare" measured values to theoretical values, always compute the error in percent.

- Repeat Steps 2-7 using Multisim and the virtual scope to solve for and plot the resistor voltage $v_R$. Compare the experimental results for $v_R$ to the simulation results.
- Write the analytical expression for the inductor current for the series *RL* circuit that you experimented with in Steps 2-7.
- Use the measured $\tau$ in Step 7 and the measured value of the 680$\Omega$ resistor in order to estimate the inductance *L*. Compare this value to the nominal 1mH value.
- Use Multisim to validate the results that you obtained in Steps 8 and 9 for the series *RL* circuit which employed the (small) 47$\Omega$ resistor. Compare the experimental results to the results in Figures 13-15.
- Use the experimental results to write the analytical expression for the charging cycle portion of the inductor current for the circuit in Step 8.
- Explain why the minimum and maximum values of the resistor voltage in Step 6 are different from 0V and 4V, respectively.
- Use the measured $\tau$ in Step 8 and the measured values of *R* and $R_o$ (assume $R_S$ = 50$\Omega$) in order to estimate the inductance *L*. Compare this value to 1mH.
- Use the time shift value that you measured in Step 10 to compute the phase shift (in degrees) between the integrator's output and input voltage signals.
- Use Multisim to simulate the integrator circuit in Step 10. Compare your simulation result for $v_o$ to the experimental result that you obtained in Step 10, and to the theoretical result obtained using Equation (17).
- Compare the experimental lower limit for *f* (from Step 11) to the theoretical value implied by the constraint:

$$\frac{AR}{2\pi fL} < |v_{sat}|$$

Here, *A* is the sine wave amplitude (2V). Assume $|v_{sat}|$ = 14.