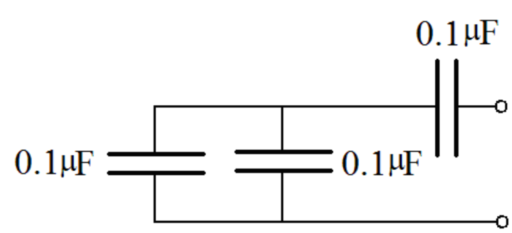
Experiment 8
Lab Activity

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

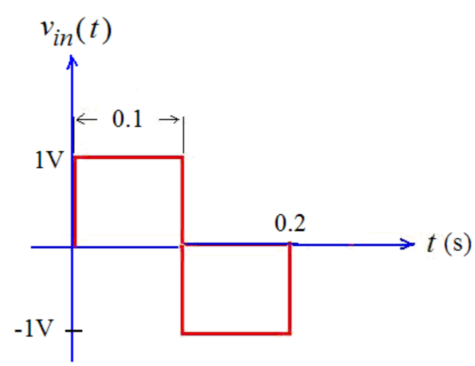
1. A 10μF capacitor has a voltage drop of 16V between its terminals. How much charge does it store? How much energy does it store?
2. A ceramic (disc shaped) capacitor has a diameter of 12mm and a capacitance of 0.01μF. Find the capacitor's plate separation. What is the (approximate) break down voltage? Suggest a safe working voltage range for this capacitor.
3. A capacitor is printed with the following information: 151J. What is the rage of its capacitance?
4. A 1nF capacitor is used in a circuit and has $v_C(t) = 10\cos(500\pi t)$ Volts. Determine the capacitor current $i_C(t)$.
5. Find the equivalent capacitance for the following network of capacitors.



6. Consider the circuit in Figure 12. Assume $C = 0.1\mu\text{F}$ and $R = 100\ \text{k}\Omega$. What is the value of τ? What should be the frequency of the square wave source be in order to clearly display the charge/discharge cycles of the capacitor?
7. When measuring the time constant of a circuit from the exponential voltage signal $y(t) = Ae^{-t/\tau}$ using a scope, it is more convenient to measure the time $t_{1/2}$ at which the signal amplitude is $A/2$. Show that the time constant can be computed as

$$\tau = \frac{t_{1/2}}{\ln(2)} \cong 1.44 t_{1/2}$$

8. Assume V_S = 5V for Problem 6. Use Multisim (and its virtual scope) to solve for and display the capacitor voltage. Employ the scope's cursors to measure the time constant.
9. Consider the voltage integrator circuit in Figure 13. Assume R = 100kΩ, C = 0.1μF and the op-amp saturation voltage is 14V. Let v_{in} = $A\cos(2000\pi t)$. What is the upper limit on A for the integrator to operate as a linear circuit?
10. Consider the circuit in Figure 13 with RC = 0.01s and zero initial capacitor energy. Assume the input voltage is given by the signal



Use Equation (8) to solve for $v_o(t)$. Sketch $v_o(t)$.

Laboratory Activity

Required components:

One 5.6kΩ resistor (±5%, ½ W)

One 10kΩ resistor (±5%, ½ W)

One 100kΩ resistor (±5%, ½ W)

One 0.01μF ceramic disk capacitors (±20%, 100V)

Three 0.1μF ceramic disk capacitors (±20%, 100V)

One 0.1μF multilayer (conformal coated) ceramic capacitors (±10%, 100V)

LM741 op-amp

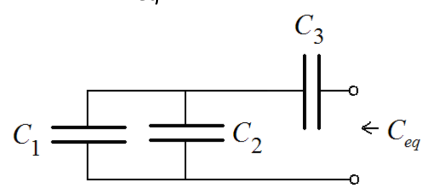
Scotch tape

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 and capacitance, set the multimeter to record the displayed reading accurate to two significant digits to the right of the decimal point.

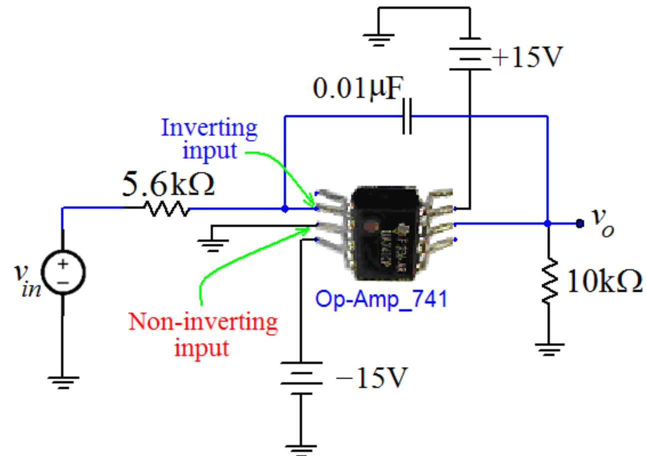
1. Obtain the above resistors from your lab instructor and measure and record their actual resistance. Also, obtain a 0.1μF *multilayer ceramic* capacitor from your instructor and use the multimeter to measure its capacitance. Write down the codes that are printed on this capacitor. Now, hold the capacitor firmly between your thumb and index fingers (so as to heat it up) for 30 seconds and then measure its capacitance.
2. Obtain three 0.1μF *ceramic disk* capacitors from your lab instructor. Write down the codes that are printed on this type of capacitor. Tag the capacitors with labels C_1, C_2, and C_3, respectively. You may use a small piece of scotch tape for the label. Measure and record the capacitance of each capacitor. Now, hold capacitor C_1 firmly between your thumb and index fingers (so as to heat it up) for 30 seconds and then measure and record its capacitance.

3. Construct the following network of capacitors (employ the three ceramic disk capacitors) and use the multimeter to measure its equivalent capacitance C_{eq}.



4. Build the series *RC* circuit shown in Figure 12. Use the disk capacitor labeled C_1 and the 100kΩ resistor.
5. Use the measured values of C_1 and R to compute the time constant τ.
6. Set the function generator to generate the square voltage signal in Figure 11. Let V_S = 10V and set the frequency to $1/(10\tau)$. Us 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.
7. Use the scope (apply autoscale) to display the capacitor voltage. Save the display as an image file.
8. Adjust the scope's horizontal and vertical gain so as to display the largest possible (stable) single capacitor discharge cycle. Save the display into an image file.
9. Employ the scope's cursors to measure the time constant, τ. Here, τ is the time it takes the capacitor to discharge from 10V to $10/e \cong$ 3.68V. Alternatively, you may use the method of Problem 7.
10. Repeat Steps 5-9 using the 10kΩ resistor.
11. Replace the 10kΩ resistor by the 100kΩ resistor. Change the frequency of the square wave to $1/(2\tau)$. Press the autoscale key on the scope. Save the display as an image file. Use the scope to determine the *average*, *minimum* and *maximum* values of the capacitor voltage.
12. Measure and record the values of the 5.6kΩ resistor and the 0.01μF disc capacitor. Build the op-amp integrator circuit shown below. Let the input be a (zero-offset) square wave with 6V peak-to-peak and 1kHz frequency. Use the scope to verify the amplitude of the input signal (you may need to calibrate the probe if the square wave looks distorted). Display the input and the output

signal on the scope (apply averaging if the signals look noisy). Save the display as an image file.



13. Slowly increase the peak-to-peak value (V_{pp}) of the square wave by 0.1V increments until the integrator output is about to saturate. Stop and record V_{pp}.
14. Now, keep the same settings as in Step 13. Press the sine wave key on the function generator. Save the display as an image file. Repeat for the following input signals: triangular and ramp.
15. 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 and capacitor 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.

- The multilayer ceramic capacitor that you have measured in Step 1 has the code "104K". Is the measured value of this capacitor consistent with its tolerance rating?
- Compute the error between the measured capacitance of C_1, C_2, and C_3 and their 0.1μF nominal value. Based on such errors try to predict the tolerance of those ceramic disk capacitors.
- Compute the change in capacitance (in percent) for the 0.1μF disc and multilayer capacitors due to the increase in temperature (refer to Steps 1 and 2). What happens to the capacitance as temperature increases? Which is the more stable capacitor?
- Compare the measured value of C_{eq} in Step 3 to the theoretical value.
- Repeat Steps 4-9 using Multisim's transient response analysis feature. Compare the experimental results to the simulation results.
- Write the analytical expression for the capacitor voltage for the circuit that you measured in Steps 4-9.
- Use the measured τ in Step 9 and the measured value of the 100kΩ resistor in order to estimate the capacitance of C_1. Compare this value to the measured value of C_1 that you obtained in Step 2.
- Compare the voltage signals in Step 7 and Step 11. Why is the peak voltage of the capacitor less than the peak of the supply voltage, at higher frequencies?
- Use Multisim to simulate the integrator circuit in Step 12. Compare your simulation results to those obtained in Step 12, and to the theoretical result obtained using Equation (8).
- Assuming that the input signal is a (zero-offset) square wave with peak-to-peak voltage V_{pp} and frequency f (in Hz), it can be shown that the output of the voltage integrator (shown in Figure 13) will saturate if

$$\frac{V_{pp}}{8\,fRC} > |v_{sat}|$$

With the ±15V bias, the op-amp saturation voltage ($|v_{sat}|$) is approximately 14V. Compare the experimental value of V_{pp} that you obtained in Step 13 to the theoretical value (employing the measured *R* and *C* values).

- Verify that each of the output signals that you have obtained in Step 14 is the integral of its associated input signal.