**LAB 4: The RC and RLC circuits**

Name:

**Objective:**

To measure RC time constant and resonant frequencies and response curve of RLC circuit.

**Learning Outcomes:**

1. The ability to use the oscilloscope to measure the ac signal parameters.
2. To identify the resonant frequency of an RLC circuit and measure the response curve

**Instrument/Component:**

Waveform/Function Generator

Oscilloscope

Multimeter

Resistors: 100Ω, 200Ω, 400Ω, 10kΩ

Variable Resistor: 0-10kΩ, 0-50kΩ

Capacitors: 0.01uF, 0.001uF

Inductor: 25mH/110mH

**Task 1: Measurement of an RC time constant**

An RC “low-pass" filter circuit is shown in Fig. 4.1. Use R=10kΩ (use 0-50kΩ variable resistor) and C=0.001µF, square wave signal, 5000Hz, 8Vpp.



**Figure 4.1**

Circuit theory shows that if the circuit is fed a step input (or low frequency square wave) that the output will show an RC charging curve that approaches the limiting DC voltage exponentially with a time constant of RC. In other words, if the initial voltage across the capacitor is some positive voltage V0 and then the input drops to zero volts, the capacitor voltage VC will decay according to

 (1)

If the input were not a step or low-frequency square wave but a sine wave, the ratio of the output amplitude, Vout to the input amplitude, Vin would depend on the frequency *f* according to

 (2)

The RC constant can be found in two ways: either by measuring the “half-life" of the decay, or by measuring the frequency at which the output amplitude drops by a specific amount. In the following, we'll use the digital oscilloscope to try both methods.

**Method 1: Measuring the “half-life" of the decay.**

1. Build the RC circuit shown in Fig. 4.1 on the breadboard. Use CH2 of the Oscilloscope to measure signal across the capacitor.
2. Connect the signal from the Function Generator to CH1 of the Oscilloscope.
3. Set up the function generator to produce a 5000 Hz square wave of 8 volts peak-to-peak amplitude, and look at both the input and output signals of the RC circuit on the Oscilloscope. You should see something like Figure 4.2.



CH1

CH2

**Figure 4.2**

Display showing both the input square wave (CH1) and the output waveform

that is rounded due to RC charging (CH2).

1. Next, turn CH1 off, and use the SEC/DIV knob, the VOLTS/DIV knob and the horizontal and vertical POSITION knobs to expand the amount of screen space taken up by a downward-going part of the RC-circuit output waveform, as is shown in Figure 4.3. Notice that an 8 volt peak-to-peak signal takes up the full vertical range of the screen.

  
**Figure 4.3**

Expanded view of the signal in CH2 showing the cursors placed to measure

one half-life time of the decay (7.9µs).

1. The half-life time, **T1/2 is defined as the amount of time it takes for the signal to drop by one-half of wherever it was when you started the measurement**. So if the full peak-to-peak value is 8 volts, and we start t = 0 at the beginning of its drop from +4 volts towards -4 volts it will drop by 4 volts (to 0 volts) at t = T1/2, and then it will drop by another 2 volts (to -2 volts) at t = 2T1/2, and then by another 1 volt (to -3 volts) at t = 3T1/2.

Use the cursors to measure T1/2 for your circuit.

Answer:

1. From Eq. (1), it can be deduced that RC = T1/2 /ln 2.

Calculate RC for your circuit using your measurement, and compare it to the value you expect from the part values (calculation).

Answer:

**Method 2: Measuring the frequency at which the output amplitude drops by a specific amount**

To try the second method of comparing the input to the output using sine waves and Eq. (2), note that when 2π*f*RC = 1, Vout/Vin = 1/√2 = 0.707.

1. Set the function generator to produce a sine wave of 10 volts peak-to-peak amplitude.
2. Turn on both CH1 and CH2 so that you can see the input and the output.
3. Set up automated measurements to make the following: CH1 peak-to-peak amplitude, CH2 peak-to-peak amplitude, CH1 frequency and/or period. You should see that the CH1 amplitude measurement gives close to 10 volts.
4. Position the 0 volt markers of both channels at the horizontal centerline of the display, so that each trace is symmetric about the center.
5. Now turn the frequency knob **up** until you see the CH2 amplitude drop to (about) 7.07 volts. This is the frequency at which 2π*f*RC 1. This is the condition that is shown in Fig. 4.4.



**Figure 4.4**

Digital scope measurements of sine wave response of an RC circuit.

The larger waveform is the signal at the input of the RC circuit,

and the smaller waveform is the signal at the output.

The frequency of the sine wave is set so that

the ratio of the output to input amplitudes is about 0.7.

1. From this frequency, calculate the value of RC (In the example of Fig. 4.4, the period of 70.07µs corresponds to a frequency of 14,270 Hz, which gives RC = 1/(2π x 14,270)s or 11.2µs, which is close to the value obtained through the half-life measurement).

Answer:

1. AC circuit theory also predicts that at this frequency there should be a phase shift between the input and output of 45o. You can measure this with the cursors. First use the cursors to measure the points at which the two waveforms cross the 0 volt line. Then use the cursors (or automated measurement) to find the full period of the sine wave. The ratio of these two values times 360 gives the phase shift in degrees (From Fig. 4.4, one obtains a phase shift of 9µs/70µs x 360 = 46o).

What do you get for your circuit?

Answer:

**Task 2: Force Damped Oscillator: The RLC Circuit**

1. Assemble the experimental circuit shown in Figure 4.5 using the values: R=400 Ω, C=0.01μF, and L = 25mH or 110mH.



**Figure 4.5**

1. Calculate the resonant frequency, *f*0 (not the angular frequency, ωo), in Hz by using the following formula:

 (3)

Calculation:

1. Set the signal generator frequency near the value calculated with a voltage amplitude of about 3 Volts. You can set the signal generator output precisely by unhooking the RLC circuit from the generator and directing the output only to the oscilloscope. Set the oscilloscope to the AC Volts setting, with the sensitivity set to the 20V setting.
2. With the RLC circuit set up, measure the voltage across the resistor. Now vary the frequency *f* to find the maximum voltage (it will likely not be the full 3V). This frequency will probably be a little different from your calculation.
3. Take many (at least 4 on each side of *fo* ) measurements of *V* in the vicinity of the resonant frequency ensuring that you tune the signal generator through a broad range of frequencies so you see the voltage drop off by at least one-third on each side of the peak voltage. Record your data in the following tables*.*



1. Now change R to 200 Ω and repeat the measurements.
2. Now change R to 100 Ω and repeat the measurements.

**Analysis:**

1. Plot Voltage vs. Frequency (y vs. x) for all 3 data sets on a single grid, plotting the data for *R* = 400 Ω first as it should be broadest. Use 3 different markers: solid circles for 400 Ω, hollow squares for 200 Ω, and small x’s for 100 Ω. Connect each different data set with a smooth line forming a bell-shape curve.



1. How do the resonant frequencies compare in the 3 plots? Is this expected? Explain.

Answer:

1. From your plots, measure the Quality factor, *Q*, of each of the 3 curves. Show your work for at least one value. Use the given equation:

 (4)

(Hint: See Figure 4.6)



**Figure 4.6**

1. Calculate *Q* for each of the three resistances: 100, 200, and 400 ohms. Show work for calculations. Use following equation:

 (5)

Answer:

1. Plot *1/Q* (measured from your plots) versus *R* on the small grid below. Is this a straight line, as expected? Draw a best-fit line and measure its slope. How close is your measured slope to what it should be?

Hint : Remember Equation 5.



Answer: