**EXPERIMENT: THE OSCILLOSCOPE AND A.C. CIRCUITS**

[Equipment list: 20 MHz Oscilloscope, Function Generator (5 MHz max.), Digital Multimeter, Variable Decade Resistor Box, 1-milliHenry Inductor, 1-microFarad Capacitor, 4.4-microFarad Capacitor]

**Overview:**

**The Oscilloscope**

Equipment that visually displays the physical properties of various sorts is desirable in science. We hear sound, but only within a particular range of frequencies can we do this. Equipment more sensitive than the human ear can detect sound waves outside our range of hearing. An oscilloscope can visually display these sound waves onto a screen that has a grid to reference the waveforms. Voltage measurements of a circuit are most difficult to sense by us. However, the oscilloscope responds to voltage values and displays them onto its screen.

The oscilloscope is equipped with an internal variable saw tooth generator that can supply voltage (see figure 1) along the horizontal direction of the screen. The horizontal axis on the screen is then the time axis. As the voltage is increased uniformly, the spot of light sweeps across the screen. When the voltage suddenly drops to zero (Where on the saw tooth pattern would this happen?), the spot of light goes back to its initial position.

Slow Sweep Rate Fast Sweep Rate

Voltage Voltage

Time Time

Figure 1

If we apply a voltage with the form V = Vo sin 2πft to the vertical defection plates, the beam would move up and down and trace out a vertical line. If we now place a saw tooth pattern voltage on the horizontal deflection plates, the beam will sweep left to right while it moves vertically up and down. The trace is then a graph of the applied vertical signal with time.

Figure 2

**Procedure:**

**A. Frequency Measurements**

The frequency of a recurring event is equal to the number of times the event happens over a certain amount of time. If something is exhibiting cyclic oscillations the number of cycles per second can be determined. One cycle per second is equal to one Hertz. The frequency can be determined from the period of the oscillation. The period is how much time it takes to complete one oscillation. The relationship between the frequency and the period is then just:



The frequency f is equal to the inverse of the period T. One complete oscillation needs to be measured in time. An example of a complete oscillation is that of a swinging pendulum. As the pendulum swings it goes from the left-most side of its swing to its right-most side and back again to the left-most side. One oscillation is this full action of the pendulum swinging out and returning to its starting position. One oscillation of the electrical input of a sinusoidal wave to the oscilloscope is very much like this.

Hook up the function generator (an AC source of variable frequency) to the CH 1 or X input. **Set function generator for 100 Hz**. Adjust intensity, focus and position. Have at least one complete cycle on screen.

Determine the period and from this calculate the frequency. Record the Period and calculate the Frequency on the worksheet.

Period: \_\_\_\_\_\_\_\_\_\_\_\_ Frequency: \_\_\_\_\_\_\_\_\_\_\_\_

Question 1: Does it agree with the display on the function generator?

**Set the function generator to 5000 HZ. Repeat above.**

Determine the period and from this calculate the frequency. Record the Period and calculate the Frequency on the worksheet.

Period: \_\_\_\_\_\_\_\_\_\_\_\_ Frequency: \_\_\_\_\_\_\_\_\_\_\_\_

Question 2: Does it agree with the display on the function generator?

**B. Voltage Measurements**

Set the amplitude level of the function generator at about half of its travel.

What is the peak voltage? Record this on the worksheet.

Peak Voltage: \_\_\_\_\_\_\_\_\_\_\_\_

Increase the amplitude of the function generator to maximum and determine this voltage. Record this on the worksheet.

Peak Voltage: \_\_\_\_\_\_\_\_\_\_\_\_

**AC Circuits and Resonance**

Object: The purpose of this part of the experiment is to utilize the oscilloscope in determining the behavior of resonant and non-resonant AC circuits.

**Theory:** This experiment is concerned with measuring the potential drops across various circuit elements in series alternating current circuits. Additionally, it may be shown that these potential drops are not in phase with each other (even though both may be sinusoidal, they do not achieve their maxima simultaneously with time). Determination will be made of the phase angle between these potential drops.

The usual direct current (DC) meter is inadequate for these measurements due to its inability to respond to a signal that is rapidly varying with time. An alternating current (AC) meter has much the same deficiency because of the inertial lag of the indicating pointer. Thus, we must use different instrumentation that is not subject to these disadvantages.

In a series RLC circuit, it has been shown that the impedance is given by:

where XL = 2πfL, and XC = 1/(2πfC). We see then that the impedance will vary with frequency, f, and this may be observed through the use of the oscilloscope.

Additionally, the potential drop across the resistive element will not be in phase with that across the reactive elements. This phase angle between the applied voltage and the voltage across the resistive element is given by (see figure 3):

VL = IXL

VL - VC

ϕ

VC = IXC VR = IR

figure 3

By using the dual trace function, this may be easily observed. Note that if XL = XC, then ϕ is equal to zero and the condition known as resonance occurs. At this point, the circuit behaves as if it were entirely resistive.

**C. RC Circuit: Determination of 4.4μF Capacitor (tan φ = -XC/R)**

Connect the 4.4 micro-Farad capacitor and a 25-ohm resistor box in series with the function generator. Feed the oscillator output to Channel 2 input of the oscilloscope so it will measure the applied voltage on the RC circuit. Connect the red input post of Channel 1 input to the junction between the resistor and the capacitor. Channel 1 is measuring the voltage across the resistor (see figure 4). This signal is proportional to the current in the circuit and is in phase with the current signal.

Capacitor

Oscilloscope

Channel 2 Generator

Channel 1

Resistor

figure 4

You should notice the two signals are not in phase (see figure 5), and the phase changes as a function of the oscillator frequency. Change the frequency and see if the phase changes. If not, your circuit is wired wrong. Try again.

VR V

Φ

figure 5

For the frequencies listed in table 1 determine the phase angle difference Φ. In order to do this, you will need to determine a scale factor measured in degrees/division. Do this by dividing one whole wave cycle (360°) by the number of divisions wide the wave cycle is as measured on the oscilloscope screen. Measure the number of divisions that Φ is equal to and multiply this by the scale factor to get Φ in units of degrees. Then, calculate the capacitance of the capacitor for each phase angle difference determined. Note: The phase angle difference in an RC circuit is negative. Finally, determine the average capacitance value and compare this to the manufacturer’s value of 4.4μF.

Table 1 (Use the Table 1 on the worksheet to record and calculate these values)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Frequency | Degrees/Division | Φ (# of Divisions) | Φ (Degrees) | Capacitance |
| 1000 Hz |  |  |  |  |
| 1500 Hz |  |  |  |  |
| 2000 Hz |  |  |  |  |
| 2500 Hz |  |  |  |  |
| 3000 Hz |  |  |  |  |

CAvg = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ (Determine the average capacitance on the worksheet.)

**D. RC Circuit: Determination of 1μF Capacitor (tanφ = -XC/R)**

Connect the 1 micro-Farad capacitor and a resistor box, set to 100-ohms, in series with the function generator. Feed the oscillator output to Channel 2 input of the oscilloscope so it will measure the applied voltage on the RC circuit. Connect the red input post of Channel 1 input to the junction between the resistor and the capacitor. Channel 1 is measuring the voltage across the resistor. This signal is proportional to the current in the circuit and is in phase with the current signal (see figure 6).

For the frequencies listed in table 2 determine the phase angle difference Φ. Then, calculate the capacitance of the capacitor for each phase angle difference determined. Note: The phase angle difference in an RC circuit is negative. Finally, determine the average capacitance value and compare this to the manufacturer’s value of 1 μF.

Table 2 (Use the Table 1 on the worksheet to record and calculate these values)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Frequency | Degrees/Division | Φ (# of Divisions) | Φ (Degrees) | Capacitance |
| 1000 Hz |  |  |  |  |
| 1500 Hz |  |  |  |  |
| 2000 Hz |  |  |  |  |
| 2500 Hz |  |  |  |  |
| 3000 Hz |  |  |  |  |

CAvg = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ (Determine the average capacitance on the worksheet.)

**E. RL Circuit: Determination of 1 milli-Henry Inductor (tanφ = XL/R)**

The Inductor is simply a long wire wrapped in a coil and thus has a resistance associated with it. Measure the resistance of the inductor with the digital multi-meter and record this value.

RL = \_\_\_\_\_\_\_\_\_\_Ω (Record this on the worksheet.)

The resistance of the circuit is the series combination of the resistance of the inductor and the resistance of the decade resistor box. Change the decade resistor box back to a 25Ω setting and record the sum of the inductor and the decade resistor box.

RSum = RL + R = \_\_\_\_\_\_\_\_\_\_Ω (Calculate this on the worksheet)

Connect the 1 milli-Henry Inductor and the decade resistor box in series with the function generator. Feed the oscillator output to Channel 2 input of the oscilloscope so it will measure the applied voltage on the RL circuit. Connect the red input post of Channel 1 input to the junction between the Resistor and the Inductor. Channel 1 is measuring the voltage across the resistor. This signal is proportional to the current in the circuit and is in phase with the current signal.

For the frequencies listed in table 3 determine the phase angle difference Φ. Then, calculate the inductance of the inductor for each phase angle difference determined. Note: The phase angle difference in an RL circuit is positive. Finally, determine the average inductance value and compare this to the manufacturer’s value of 1 mH.

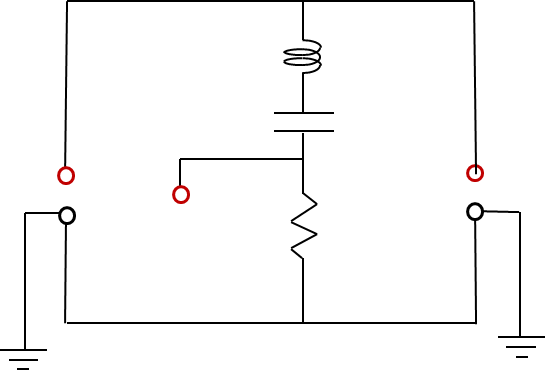
Table 3 (Use the Table 1 on the worksheet to record and calculate these values)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Frequency | Degrees/Division | Φ (# of Divisions) | Φ (Degrees) | Inductance |
| 3000 Hz |  |  |  |  |
| 3500 Hz |  |  |  |  |
| 4000 Hz |  |  |  |  |
| 4500 Hz |  |  |  |  |
| 5000 Hz |  |  |  |  |

LAvg = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ (Determine the average inductance on the worksheet.)

**F. Resonance of an RLC circuit**

Connect a 15-ohm resistor, the 1 micro-Farad capacitor, and the 1 milli-Henry inductor in series with the function generator (see fig. 6). Again, look at the signals of the applied voltage and the voltage across the resistor. Adjust the frequency until the phase angle becomes zero. Record this frequency displayed on the function generator.



Capacitor

Inductor

Figure 6

Function Generator

Resistor

Oscilloscope

Channel 1

Oscilloscope

Channel 2

Resonant Frequency: (Record the resonant frequency on the worksheet.)

Change the frequency slightly one way and then the other to obtain a range of uncertainty for this frequency. Record and calculate these on the worksheet.

+ Frequency: \_\_\_\_\_\_\_\_\_\_\_\_

- Frequency: \_\_\_\_\_\_\_\_\_\_\_\_

Frequency Range: \_\_\_\_\_\_\_\_\_\_\_\_

Repeat the above procedure with an 80-ohm resistor. You should obtain the same resonance frequency but note the difference in the uncertainties. Record and calculate these on the worksheet.

Resonant Frequency: \_\_\_\_\_\_\_\_\_\_\_\_

+ Frequency: \_\_\_\_\_\_\_\_\_\_\_\_

- Frequency: \_\_\_\_\_\_\_\_\_\_\_\_

Frequency Range: \_\_\_\_\_\_\_\_\_\_\_\_

Using the experimentally found average values for capacitance and inductance found in parts D and E calculate the resonant frequency and compare it to the experimentally found resonant frequency.

fcalc = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ (Calculate this on the worksheet.)

**Questions for Discussion**

1. Capacitors which do not have a tolerance value listed (as in this experiment) may be as much as 20% off from the manufacturer’s stated value. How well do your values for the capacitors in parts C and D compare to their stated value?

2. The inductor in part E has a resistance that needed to be considered in the determination of its inductance value. Re-calculate the inductances of the inductor ignoring the resistance of the inductor and determine an average inductance. Comment on why it is necessary to consider the resistance of the inductor. Make a table of your work similar to the following:

|  |  |  |
| --- | --- | --- |
| frequency | Φ (degrees) | Inductance |
| 3000 Hz |  |  |
| 3500 Hz |  |  |
| 4000 Hz |  |  |
| 4500 Hz |  |  |
| 5000 Hz |  |  |

LAvg = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

3. In part F you determined the resonant frequency experimentally for two different resistance values. How do these frequencies compare to each other? How well does the calculated resonant frequency compare to the two experimentally found frequencies?

4. Using the phasor diagram (figure 5) describe what happens to the magnitude of the voltage across the circuit as compared to the magnitude of the voltage across the resistor when the circuit is in resonance and at higher and lower frequencies out of resonance.