GENERAL ELECTRICAL ENGINEERING LAB 2

AC Properties and Measurements

CH-211-B

Natural Science Laboratory

Lab Experiment 2

Experiment conducted by: Kuranage R R Ranasinghe and Abigail Christie

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JACOBS UNIVERSITY BREMEN

Author: Kuranage R R Ranasinghe

INTRODUCTION AND THEORY

An AC signal (could be a current, voltage, etc.) is a signal which consistently produces both positive and negative values during its existence. It is a periodic signal which changes direction with respect to a particular base axis in a way such that this change is reflected as negative and positive values. Power is supplied to the whole world using AC signals due to its many advantages over DC signals. In this experiment, our main objective is to look into, understand and measure the properties of AC signals produced by simple AC circuits. The most important tools used to do this experiment successfully are the Oscilloscope and Multimeter which are used to measure AC signals generated by an AC generator.

Important terminology required for a successful overview of this experiment are given below:

- Periodic Signals

  Signals that consistently repeat after a certain time period has passed. They can be described by the equation: v(t)=v(t+nT), where T is the period, n is an integer and v(t) is any periodic function (such as trigonometric functions sine and cosine). The period (T) can be used to obtain the frequency (f) of the signal for a measure of how many times per second a signal is repeated and given by the equation f=1/T.

- Arithmetic Mean Value

  This value is taken to get some information about the effects of a periodic function over time when necessary. Simply put, it is the average value of an AC signal in a circuit over a certain time. For instance, for an alternating periodic signal (an AC signal) with no DC component, the Arithmetic Mean Value would be zero. It is found using the following Equation 1, where T is the time period and v(t) is a periodic signal.

$$\bar{v} = \frac{1}{T}\int_{t0}^{t0+T} v(t)dt \qquad \text{Equation 1}$$

- Root Mean Square Value (RMS)

  The root mean square value of a quantity is the square root of the mean value of the squared values of the quantity taken over an interval. The RMS value is the effective value of a varying voltage or current. It is the equivalent steady DC (constant) value which produces the same amount of power as the AC signal. The RMS of a voltage or current signal can be calculated as follows:

$$V_{rms} = \sqrt{\frac{1}{T}\int_{t0}^{t0+T} v(t)^2 dt} \qquad I_{rms} = \sqrt{\frac{1}{T}\int_{t0}^{t0+T} i(t)^2 dt} \qquad \text{Equation 2}$$

This occurs when there is no superimposed DC value on the AC signal. However, in the case of a super imposed DC signal, the equation for the RMS current can be calculated as follows:

$$I = \sqrt{\frac{1}{T}\int_{t0}^{t0+T} (I_- + i_\sim)^2 dt} = \sqrt{\frac{1}{T}\int_{t0}^{t0+T} (I_-^2 + 2I_- i_\sim + i_\sim^2) dt}$$

Integrating over the components

$$I = \sqrt{\frac{1}{T}\left[\int_{t0}^{t0+T} I_-^2\, dt + \int_{t0}^{t0+T} 2I_- i_\sim dt + \int_{t0}^{t0+T} i_\sim^2\, dt\right]}$$

will give three terms under the root. The first and last one are like the ones for the pure DC and periodic RMS signal. The second one beside the constant $2I_-$ is the mean value which becomes zero. So the RMS value of a mixed signal is calculated

$$I = \sqrt{(I_{DC})^2 + (I_{AC})^2}$$

Equation 3: Taken from The Electrical Engineering II Lab Manual

This experiment focuses on measuring these different properties of AC signals and reasons for errors in the measurement of RMS voltages and currents, peak to peak voltages, amplitudes, and phases of the signal; specially as it passes through a simple RLC circuit which has both resistive and reactive components.

Experimental Set-up and Results

Part 1: Measurement AC Signal Properties

The AC generator, oscilloscope and the multimeter were all connected using some lab wires, a BNC cable, T-connector and a -Banana connector. The initial generator settings were as follows:

Function: sine

Frequency: 1kHz

Amplitude: $2V_{pp}$

Offset: 0V

The values for V_{pp}, $\bar{v}$ and V (= V_{rms}) were measured and recorded on the oscilloscope using the measure function. The voltage in the V_{AC} and V_{DC} range were also measured with the TENMA Multimeter. The DC offset value was then changed to 1V and all values were measured and recorded again with the appropriate instrument.

Table 1: Data from the Tenma Multimeter with a 0V offset & sine Wave Signal	
V_{AC}	0.6995V
V_{DC}	0.000V
V_{AC+DC}	0.7014V

Table 2: Data from the Tenma Multimeter with an offset of 1V & sine Wave Signal	
V_{AC}	0.6992V
V_{DC}	0.9834V
V_{AC+DC}	1.2044V

The generator settings were then replaced with:

Function: Arb-select 'Exp_Fall'

Frequency: 1kHz

Amplitude: $2V_{pp}$

Offset: 0V

This resulted in a wave with an amplitude/offset of ±1V. Once again, all measurements were repeated both with and without the 1V offset.

Table 3: Data from the Tenma Multimeter with 0V offset & Exp Fall Wave	
V_{AC}	0.4671V
V_{DC}	-0.6656V
V_{AC+DC}	0.8187V

Table 4: Data from the Tenma Multimeter with a 1V offset & Exp Fall Wave	
V_{AC}	0.4643V
V_{DC}	0.3173V
V_{AC+DC}	0.561V

Part 2: Measure AC Circuit Properties

The circuit was set up as shown in Diagram 1 below:

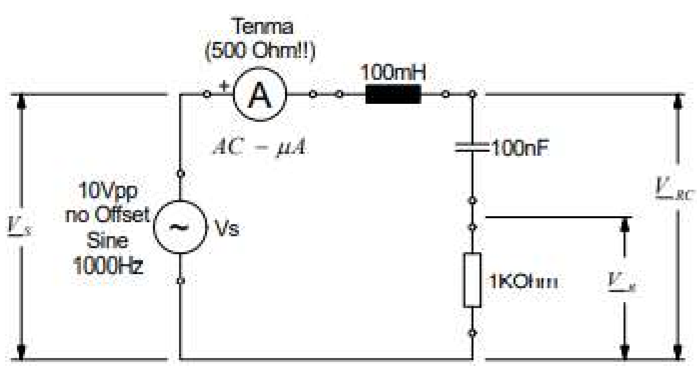

Diagram 1: Set-up for Part 2 of Experiment (Taken from Lab Manual)

An RLC-meter was used to obtain the exact impedance and element values for the inductor and the capacitor at 1KHz. The ELABO multimeter was then used to determine the exact value of the impedance for the resistor.

Table 5: Exact values of elements used in the circuit		
Inductor	Ls: 103.40mH	Rs: 395.90Ω
Capacitor	Cp: 102.09nF	Rp: 405.30kΩ
Resistor	994.1Ω	

Note that for all measurements, $\underline{\hat{v}}_S = 5V\angle 0°$ is the reference signal. The phasor current was measured with the TENMA multimeter and V_S, V_R and V_{RC} were then measured with the ELABO multimeter. The phases of V_R and V_{RC} were measured with the oscilloscope.

Table 6: Data Obtained for this Section of the Experiment		
Phasor Current	1657.5µA	
	Phasor Voltage(V)	Phase (°)
V_R	1.657	25.9
V_{RC}	3.087	-31.6
V_S	3.487V	

Part 1: Measurement of AC signal properties

-Theoretical Values of $\bar{v}$ and V of the sine wave for:

$V = f(t) = \hat{v}\sin \omega t + v_{off}$

$\omega = 2\pi f = 2000\pi$

$T = f^{-1} = 1ms$

$$V_{rms} = \sqrt{\frac{1}{T}\int_0^T (V)^2 dt}$$

$$\bar{v} = \frac{1}{T}\int_0^T f(t)\, dt$$

$$\bar{v} = \frac{1}{T}\int_0^T \hat{v}\sin \omega t + v_{off}\, dt$$

An offset of 0V

$$\bar{v} = 1000\int_0^{\frac{1}{1000}} 1\sin 2000\pi t + 0\, dt$$

$$= \left[1000\ \frac{cos2000\pi t}{2000\pi}\right]_0^{\frac{1}{1000}} = \left[1000\ \left(\frac{cos2\pi}{2000\pi} - \frac{cos0}{2000\pi}\right)\right] = \left[1000\ \left(\frac{1}{2000\pi} - \frac{1}{200}\right)\right]$$

$$\bar{v} = 0V$$

$$V_{rms} = \sqrt{1000\int_0^{\frac{1}{1000}} (1\sin 2000\pi t + 0)^2 dt}$$

$$= \sqrt{1000\int_0^{\frac{1}{1000}} \frac{1}{2}(1 - cos4000\pi t)dt}$$

$$= \sqrt{500\left(\int_0^{\frac{1}{1000}} 1dt - \int_0^{\frac{1}{1000}} cos4000\pi t dt\right.}$$

$$= \sqrt{500\left([t]_0^{\frac{1}{1000}} - \left[\frac{sin4000\pi t}{4000\pi}\right]_0^{\frac{1}{1000}}\right.}$$

$$= \sqrt{500\left(\left[\frac{1}{1000} - 0\right] - \left[\frac{sin4\pi}{4000\pi} - \frac{sin0}{4000\pi}\right]\right)}$$

$$= \sqrt{\frac{1}{2}}$$

$V_{rms} = 0.7071$ V

<u>An offset of 1V</u>

$$\bar{v} = 1000 \int_0^{\frac{1}{1000}} 1\sin 2000\pi t \; + \; 1 \; dt$$

$$= \left[1000 \; \frac{cos2000\pi t}{2000\pi} + t\right]_0^{\frac{1}{1000}} \;\; = \;\; \left[1000 \; \left(\frac{cos2\pi}{2000\pi} + \frac{1}{1000} - \frac{cos0}{2000\pi} - 0\right)\right]$$

$$= \left[1000 \; \left(\frac{1}{1000}\right)\right]$$

$$\bar{v} = 1 \; V$$

$$V_{rms} = \sqrt{1000 \int_0^{\frac{1}{1000}} (1\sin 2000\pi t \; + \; 1)^2 dt}$$

$$= \sqrt{1000 \left[\frac{3t}{2} - \frac{sin4000\pi t}{8000\pi} - \frac{\cos 2000\pi t}{1000\pi}\right]_0^{\frac{1}{1000}}}$$

$$= \sqrt{1000 \left[\frac{3}{2000} - \frac{sin4\pi}{8000\pi} - \frac{\cos 2\pi}{1000\pi} - 0 + \frac{sin0}{8000\pi} + \frac{\cos 0}{1000\pi}\right]} \quad = \sqrt{\frac{3}{2}}$$

V_{rms} = 1.2247 V

Summarized in a table, the results are:

V_{off} (V)	$\hat{v}$ (V)	$\bar{v}$ (V)	V_{rms} (V)
0	1.04	0	0.7071
1	1.04	1	1.2247

-Theoretical values of $\bar{v}$ and V of the Exponential Fall wave for:

$$V = f(t) = \hat{v}(2e^{kt} - 1) + v_{off}$$

ω=2πf= 2000π

T = f^{-1} = 1ms

V_{rms} = $\sqrt{\frac{1}{T}\int_0^T (V)^2 dt}$

$$\bar{v} = \frac{1}{T}\int_0^T f(t)\, dt$$

$$\bar{v} = \frac{1}{T}\int_0^T \hat{v}(2e^{kt} - 1) + v_{off}\; dt$$

Taking the value of V= 0.76V and t= 0.000161s during 1V offset from the hardcopy:

0.88 = $1(2e^{k*0.000142} - 1) + 1$

k = -5781.6 s^{-1}

An offset of 0V

$$\bar{v} = 1000\int_0^{\frac{1}{1000}} 1(2e^{-5781.6t} - 1) + 0\; dt$$

$$= 1000\left[\frac{-2e^{-5781.6t}}{5781.6} - t\right]_0^{\frac{1}{1000}}$$

$$= 1000\left[\frac{-2e^{-578\ \ .6}}{5781.6} - \frac{1}{1000} + \frac{2e^0}{5781.6} + 0\right]$$

$$\bar{v} = -0.6541\text{V}$$

V_{rms} = $\sqrt{1000\int_0^{\frac{1}{1000}}(1(2e^{-5781.6t} - 1) + 0)^2 dt}$

$$= \sqrt{1000\int_0^{\frac{1}{1000}}(4e^{-11563.2t} - 4e^{-5781.6t} + 1)dt}$$

$$= \sqrt{1000\left[\frac{-4e^{-115\ \ .2t}}{11563.2} + \frac{4e^{-5781.6t}}{5781.6} + t\right]_0^{\frac{1}{1000}}}$$

$$= \sqrt{1000\left[\frac{-4e^{-1\ \ \ .2}}{11563.2} + \frac{4e^{-5781.6}}{5781.6} + \frac{1}{1000} + \frac{4e^0}{11563.2} - \frac{4e^0}{5781.6} - 0\right]}$$

$V_{rms} = 0.8087$ V

An offset of 1V

$$\bar{v} = 1000\int_0^{\frac{1}{1000}} 1(2e^{-57\quad .6t} - 1) + 1\,dt$$

$$= 1000\left[\frac{-2e^{-5781.6t}}{5781.6}\right]_0^{\frac{1}{1000}}$$

$$= 1000\left[\frac{-2e^{-57\quad .6}}{5781.6} + \frac{2e^{0}}{5781.6}\right]$$

$$\bar{v} = 0.3459\,V$$

$$V_{rms} = \sqrt{1000\int_0^{\frac{1}{1000}}(1(2e^{-578\quad .6t} - 1) + 1)^2 dt}$$

$$= \sqrt{1000\int_0^{\frac{1}{1000}}(4e^{-1156\quad .2t})dt}$$

$$= \sqrt{1000\left[\frac{-4e^{-11563.2t}}{11563.2}\right]_0^{\frac{1}{1000}}} \qquad = \sqrt{1000\left[\frac{-4e^{-11563.2}}{11563.2} + \frac{4e^{0}}{11563.2}\right]}$$

$V_{rms} = 0.5882$ V

Summarized in a table, the results are:

V_{off} (V)	$\hat{v}$ (V)	$\bar{v}$ (V)	V_{rms} (V)
0	1.00	-0.6541	0.8087
1	1.00	0.3459	0.5882

-When the readings from the multimeter were considered, the DC range provided us with the mean value of the voltage and the AC range provided the RMS value of the voltage WITHOUT taking into consideration the effect of the offset.

-Determination of V_{rms} from V_{AC} and V_{DC}: $V_{rms} = \sqrt{(V_{AC})^2 + (V_{DC})^2}$:

An example calculation for V_{AC} = 0.6851V and V_{DC} = 0.0000V;

$$V_{rms} = \sqrt{(0.6851)^2 + (0)^2} \quad = 0.6851$$

The V_{rms} values for the Sine wave

Offset (V)	V_{DC} (V)	V_{AC} (V)	V_{rms} (V)	V_{AC} + V_{DC} (V) (from TENMA)
0	0.0000	0.6995	0.6995	0.7014
1.00	0.9834	0.6992	1.2066	1.2044

The V_{rms} values for the Exponential Fall wave

Offset (V)	V_{DC} (V)	V_{AC} (V)	V_{rms} (V)	V_{AC} + V_{DC} (V) (from TENMA)
0	-0.6656	0.4671	0.8131	0.8187
1.00	0.3173	0.4643	0.5624	0.5610

- Table for every signal with all measured (multimeter, oscilloscope) and calculated values:

Signal	Offset (V)	V_{pp}(V)	$\bar{v}$(Cycle Mean) (V)	V_{rms} (V) (oscilloscope)	V_{DC} (V)	V_{AC} (V)	V_{AC} + V_{DC} (V)	V_{rms} (V) (multimeter)
Sine	0	2.08	0.0158	0.729	0.0000	0.6995	0.7014	0.6995
Sine	1.00	2.08	1.02	1.260	0.9834	0.6992	1.2044	1.2066
Exp_Fall	0	2.00	-0.664	0.848	-0.6656	0.4671	0.8187	0.8131
Exp_Fall	1.00	2.00	0.342	0.593	0.3173	0.4643	0.5610	0.5624

When comparing values of V_{rms} measured by the oscilloscope and the multimeter, there is a slight difference in them. The RMS value taken from the oscilloscope is directly read from the built-in RMS function while the RMS value taken from the multimeter is calculated from the values of V_{AC} and V_{DC}. Another factor to consider is the fact that the values for V_{PP} and offset read from the signal generator might not have been exact which adds to the systematic error of the reading. Secondly, there is also some noise associated with the signal produced, and hence, the decreased resolution of the signal could also play a part in adding some error to the measurement, which in turn could affect the amplitude and RMS reading of the signal.

Another erroneous factor to consider is the use of the value k in calculated values. This value (k) was experimentally determined using a pair of values produced by an oscillator. However, it was noticed that different pairs of values for voltage and time yielded different k values. This fact reveals that the value of k that we used (-5781.6 s^{-1}) might not have been the true value, hence contributing to making the calculated values more error prone.

Part 2: Measurement of AC circuit properties

Calculation of the impedance of circuit components:

<u>Inductor</u>

L_s: 103.40mH

R_s: 395.90Ω

ω: 2πf

f: 2Khz
Impedence: Rs + jωLs
395.90 +649.68j

$$|Z_L| = \sqrt{395.90^2 + 649.68^2} \;\; |Z_L| = 760.80$$

$$Z_L(\theta) = \tan^{-1}\left(\frac{649.68}{395.90}\right) = 58.64°$$

Z_L=(760.80∠58.64°)Ω

<u>Capacitor</u>

C_p: 102.09nF

R_s: 405.30kΩ

ω: 2πf

f: 2Khz
Admittance: (Rs)^-1 + jωCp
2.4673E-6+ j6.4088E-4

Impedance: 1/Admittance

5.8947-1560j

$$|Z_C| = \sqrt{5.8947^2 + 1560^2} \;\; |Z_L| = 1560.01$$

$$Z_C(\theta) = \tan^{-1}\left(\frac{-1560}{5.8947}\right) = -89.78°$$

Z_C=(1560.01∠-89.78°)Ω

Summary of Calculated Impedances				
	Measured Value	Measured Resistance	Impedance (Ω)	Impedance Phasor (Ω)
Inductor	103.40mH	395.90Ω	395.90 +649.68j	760.80∠58.64°
Capacitor	102.09nF	405.30kΩ	5.8947+ 1560j	1560.01∠-89.78°
Resistor		994.1Ω	994.1	994.1∠0°

- Calculation of all $\hat{i}$ and $\hat{u}$ values using the nominal (theoretical) input voltage and the measured impedance values at 1kHz.

$\hat{u} = 5\angle 0^\circ$ (reference signal)

$V_{rms} = \frac{1}{\sqrt{2}} * \hat{u} = (3.54\angle 0^\circ)$

From the test circuit,

Total Impedance (Z) = $Z_R + Z_L + Z_C + Z_{Tenma}$

$= 994.1\angle 0^\circ + 760.8\angle 58.6^\circ + 1560\angle\text{-}89.8^\circ + 500\angle 0^\circ$

$= (2103\angle\text{-}25.65^\circ)\ \Omega$

Now,

$$\hat{i} = \frac{V_{rms}}{Z} = \frac{3.54\angle 0^\circ}{2103\angle -25.65^\circ} = (1.68 * 10^{-3}\angle 25.65^\circ)\text{A}$$

Voltage on inductor (U_L) = $\hat{i} . Z_L$

$= 1.68 * 10^{-3}\angle 25.65^\circ * 760.8\angle 58.6^\circ$

$= (1.28\angle 84.25^\circ)$ V

Voltage on Capacitor (U_C) = $\hat{i} . Z_C$

$= 1.68 * 10^{-3}\angle 25.65^\circ * 1560\angle -89.8^\circ$

$= (2.62\angle -64.15^\circ)$ V

Voltage on Resistor (U_R) = $\hat{i} . Z_R$

$= 1.68 * 10^{-3}\angle 25.65^\circ * 994.1\angle 0^\circ$

$= (1.67\angle 25.65^\circ)$ V

Voltage on inductor (U_{Tenma}) = $\hat{i} . Z_{Tenma}$

$= 1.68 * 10^{-3}\angle 25.65^\circ * 500\angle 0^\circ$

$= (0.84\angle 25.65^\circ)$ V

-Determination of $\hat{u}$ over every component from the measured current and voltage values.

$i_{measured}$ = 1657.5µA = $1.6575*10^{-3}$A

$i(\phi) = 25.9^\circ$

In Phasor form:

$\hat{i}_{measured} = (1.6575*10^{-3}\angle 25.9^\circ)$ A

Since all the impedances are in series, the same current flows through all of them.

$V_R = (1.66\angle 25.9^\circ)$ V

$V_{RC} = (3.09\angle\text{-}31.6^\circ)$ V

$V_{Tenma} = \hat{i}_{measured} * Z_{Tenma}$

$= 1.6575 * 10^{-3}\angle 25.9^\circ * 500\angle 0^\circ$

$= (0.829\angle 25.9^\circ)$ V

$V_C = V_{RC} - V_R$
$= (3.09\angle\text{-}31.6^{\circ}) - (1.66\angle 25.9^{\circ})$
$= (2.61\angle\text{-}64.1^{\circ})$ V

Using Kirchhoff's Voltage law:
$V_s = V_L + V_{RC} + V_{Tenma}$
$V_L = V_{rms} - V_{RC} - V_{Tenma}$
$= 3.49\angle 0^{\circ} - 3.09\angle\text{-}31.6^{\circ} - 0.829\angle 25.9^{\circ}$
$= (1.26\angle 84.9^{\circ})$ V

-Table with all measured and calculated $\hat{i}$ and $\hat{u}$ values:

Parameters	Measured	Calculated
I (μA)	$1657.5\angle 25.9^{\circ}$	$1680\angle 25.65^{\circ}$
V_{rms} (V)	$3.49\angle 0^{\circ}$	$3.54\angle 0^{\circ}$
V_L(V)	$1.26\angle 84.9^{\circ}$	$1.28\angle 84.25^{\circ}$
V_C(V)	$2.61\angle\text{-}64.1^{\circ}$	$2.62\angle -64.15^{\circ}$
V_R(V)	$1.66\angle 25.9^{\circ}$	$1.67\angle 25.65^{\circ}$
V_{Tenma}(V)	$0.829\angle 25.9^{\circ}$	$0.84\angle 25.65^{\circ}$

Through comparison, it is clear that the measured values and calculated values for the voltage and current parameters are extremely close and lie with a difference of less than 10%. Although these values are perfectly acceptable, since they are not exactly identical, we must discuss errors in our measurements. One of the error sources is that the peak to peak voltage taken from the signal generator is not a true value and this causes a difference in measured values in comparison to the calculated values. Similarly, another error source is the RLC meter when it was used to measure the impedances of the capacitor (in a parallel arrangement) and inductor (in a series arrangement). The measured values, although very accurate, are not true values and are hence erroneous. The slight difference in measured and calculated values is reasonable when both these factors are taken into account.

-Calculation for the impedance (resistance and reactance) of R, L and C from the measured current and voltages and determining the element values:

$\hat{i}_{measured} = (1.6575*10^{-3}\angle 25.9^{\circ})$ A

The measured voltages across each quantity are:

$V_L = 1.26\angle 84.9^\circ$
$V_C = 2.61\angle -64.1^\circ$
$V_R = 1.66\angle 25.9^\circ$

Measured values of each respective impedances are:

$Z_L = \frac{V_L}{i_{measured}} = \frac{1.26\angle 84.9^\circ}{1.6575*10^{-3}\angle 25.9^\circ} = (391.52 + 651.60j)\ \Omega$

$Z_C = \frac{V_c}{i_{measured}} = \frac{2.61\angle -64.1^\circ}{1.6575*10^{-3}\angle 25.9^\circ} = (0 - 1574.66j)\ \Omega$

$Z_R = \frac{V_R}{i_{measured}} = \frac{1.66\angle 25.9^\circ}{1.6575*10^{-3}\angle 25.9^\circ} = 1001\ \Omega$

Representing in the same way as an RLC meter:

For Inductor:
$Z_L = R_S + j\omega L_S$
Calculated impedance value:
$R_S = 391.52\Omega$
$L_S = \frac{651.60}{2000\pi} = 103.7\text{mH}$

For Capacitor:
$Y_C = (\frac{1}{R_p}) + j\omega C_P$
Calculated value: $Z_C = (0 - 1574.66j)\ \Omega$
$Y_C = \frac{1}{Z_C} = (-6.351*10^{-4}j)\ S$
Hence,
$R_P = 0\Omega$
$C_P = \frac{6.351*10^{-4}}{2000} = 101.1\text{nF}$

-Table for all measured and calculated element values:

Element Values	Measured	Calculated
R_S (Ω)	395.90	391.52
L_S (mH)	103.4	103.7
R_P (kΩ)	405.30	0
C_P (nF)	102.09	101.1
Resistor R (Ω)	994.1	1001

The measured and calculated values are very close to each other apart from the calculated value for R_P, which is the impedance of the capacitor. This anomaly could be due to different erroneous factors within the data. One of the main sources for error is the usage of the RLC meter to measure the respective impedance since the steps to measure the impedance with a different connection in the circuit arrangement could result in an error in the reading of the meter. Another error could have occurred while measuring current from the TENMA multimeter since the supplied signal was AC and regularly changing. Due to this some error could have been introduced into the system and hence, the difference between measured and calculated values. Finally, the noise in the oscilloscope (which results in a low-quality resolution) while measuring phase difference could also have played a part in contributing to this error as well as the usage of connecting leads which themselves have a resistance (impedance) and the capacitance unit which has the same problem. Due to these external impedances in the system, the values could also be changed respectively, adding to the error.

CONCLUSION

The experiments carried out in this lab emphasized on key concepts regarding AC signals and its associated properties (peak values and amplitude, RMS values and offsets). The signal generator used to generate the actual AC signals and the oscilloscope which was used to measure those signals played an important role in helping us obtain the values necessary for an accurate analysis of the properties in an AC signal. Another topic covered here was the use of phasors and their respective calculations regarding impedances.

In the first part of the experiment, both the sine and the Exponential Fall wave were analyzed. These signals were generated using the signal generator and the respective properties were obtained using the oscilloscope. Voltages were measured from both the oscilloscope and multimeter as it was known that the DC mode in a multimeter gives us the offset value in an AC current and that the AC mode displays the respective RMS value of an AC signal. The measurement of RMS values for voltage using the oscilloscope and multimeter was a success since the values obtained were almost identical to each other. Any deviation was put down to errors discussed in the evaluation section.

During the second part of the experiment, the effect of an AC current on a series RLC circuit was studied. A sine wave was used as the AC source using the signal generator, a TENMA multimeter was taken advantage of to measure current, an ELABO multimeter was used to measure voltages and the oscilloscope played a role in measuring the phase difference. Another piece of equipment used here was an RLC meter which was used to measure the impedance of a capacitor and inductor. Considering the measurements and calculations done for this part, most of the calculated and measured impedance values were close to each other with one exception, the R_P value in the capacitor's impedance. Since the phase angle was close to -90° in this case, it is more prone to more errors and hence, the calculated and measured values showed a large difference which disagreed with theory. For an in-detail discussion of the probable error sources, refer to the evaluation section.

All objectives regarding this lab were successfully achieved and a thorough understanding of AC signals and its properties was reached.

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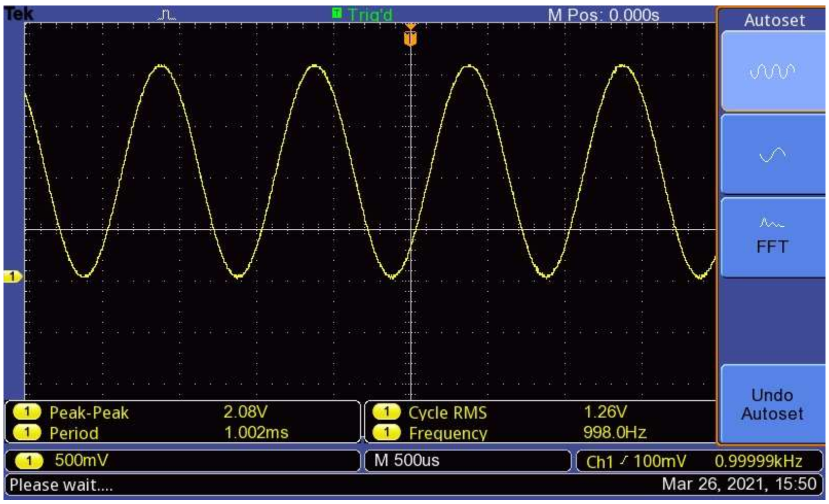
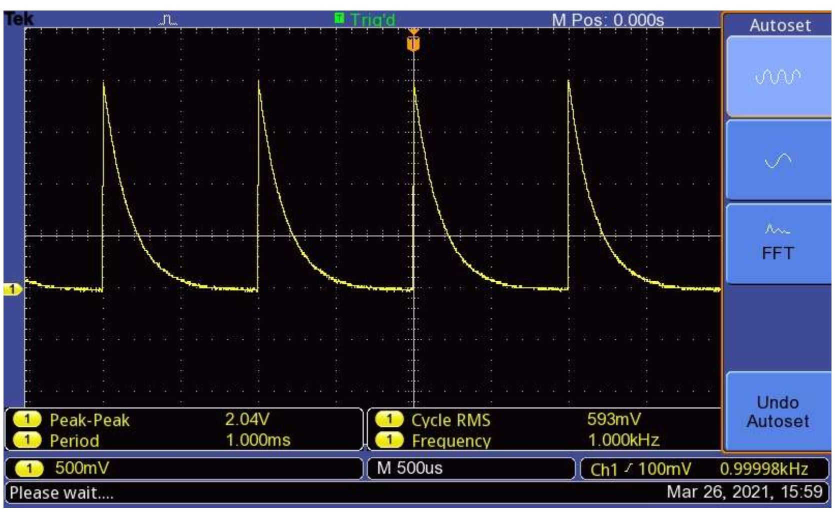
3. Phasor Calculator: https://ejl.neocities.org/
4. Tektronix Oscilloscope TBS Series Manual URL:
   http://www.faculty.jacobs-university.de/upagel/01.0.generaleelab/01.5.0.instrument_manuals/01.5.5.tbs1000b_oscilloscope/index.html

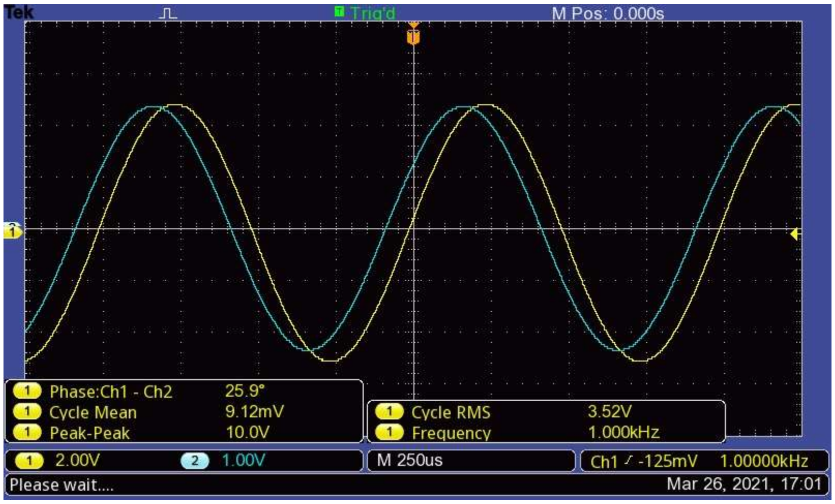
Hardcopies from the Oscilloscope



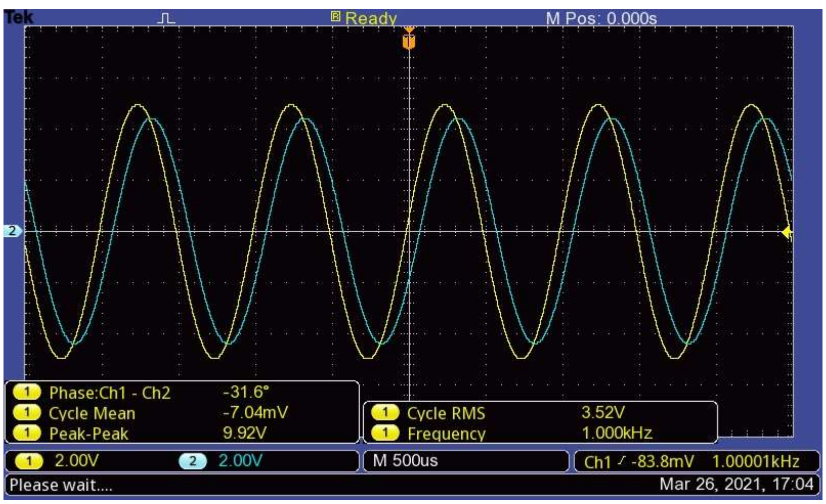
Sine wave with an offset of 1V



Exp_Fall wave with an offset of 1V



Sine wave showing a phase difference in RLC circuit 1



Sine wave showing a phase difference in RLC circuit 2