Jacobs University Bremen

Natural Science Laboratory
Electrical Engineering Module II

Spring Semester 2023

Lab Experiment 2 – AC Properties And Measurements

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Place of execution	: Teaching Lab EE
Date of execution	: March. 10, 2023

1 Introduction

This experiment's purpose is to allow the investigation of AC properties of signals, most importantly, to show the behavior of AC circuits. In this experiment, we observe periodic signals and analyze the behavior of an RCL circuit. Periodic signals are described by the equation

$$v(t) = v(t + nT)$$

where v(t) might be any periodic function, n any integer number and T is the time that it takes for one period to elapse. The period can be used to obtain the frequency, which, in the case of simple signals, we can describe as being the number of cycles per second. It is described by the relation

$f = \frac{1}{T}$Hz where Hz = Hertz is the unit of frequency.

To find out the effects of a periodic function over time, it may be easier to use the **arithmetic mean** value for current, voltage, or power. The **arithmetic mean value** for voltage, for example, is described as

$$\bar{v} = \int_{t_0}^{t_0+T} v(t)\, dt$$

For signals with no DC component, the mean value over time is zero. To make different electrical quantities comparable, the RMS was introduced, and it is defined as follows for current and for voltage:

$$I = \sqrt{\frac{1}{T}\int_{t_0}^{t_0+T} i(t)^2 dt} \quad \text{or} \quad V = \sqrt{\frac{1}{T}\int_{t_0}^{t_0+T} v(t)^2 dt}$$

And when we have a superimposed DC value, the equation may be simplified to be:

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

To measure the RMS and the mean values of electrical quantities, we may use specially designed instruments, which work independently of frequency and signal shape, or we can use the oscilloscope. The oscilloscope, however, requires that at least one full period of the signal is visible. The multimeter is also usable, but only if a "True RMS" multimeter is used, and the frequency of the signal we wish to measure lies within the bandwidth in the specification of the multimeter.

To analyze an AC circuit with only resistive components, we can take the RMS voltage, as there is no phase shift. If the frequency is low, then we can also use a multimeter. However, if we have an impedance with a reactive component, we have to measure the magnitude and phase of each component. The multimeter may be used for low frequencies, but to observe a phase shift an oscilloscope is necessary.

A reference signal must be defined, and the phase of all the other signals in the oscilloscope will be measured relative to this reference signal that we define.

If the frequency is low, the multimeter may be used for the magnitude of V and I.

2 Execution

Part 1: A Linear Network

Tools and Equipment:
TEKTRONIX TBS1072B Oscilloscope, TENMA multimeter, Function generator

Preparation:
The generator, the oscilloscope, and the multimeter are connected by a BNC cable, the BNC T-connector and the BNC-Banana connector with lab wires. The chain is terminated with a 50Ω resistor at the multimeter.

The function generator is set to be a sinusoidal wave at a 1KHz frequency, with an amplitude of 2Vpp, and an offset of 0V.

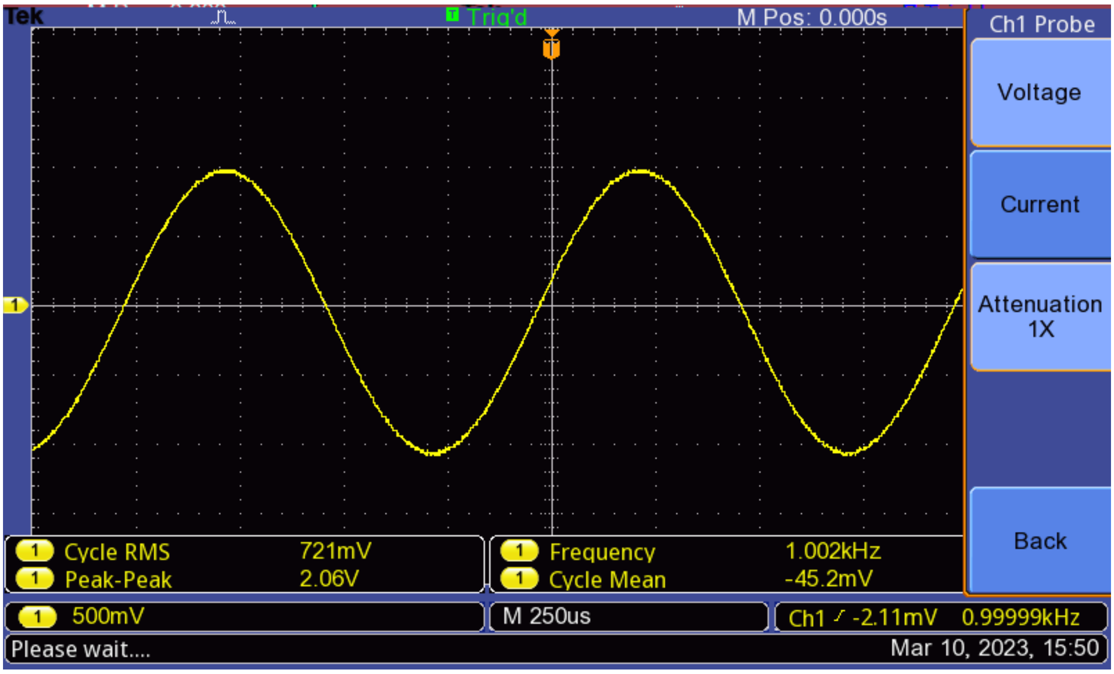

Figure 1: Oscilloscope Hard-Copy of the Sine wave generated by the function generator

Execution 1:

Using the measure function, the table below shows the values seen in the oscilloscope hard-copy when the function generator is at a 0V DC offset.

V_pp(in V)	V_mean(in mV)	V_rms(in V)
2.06	-45	0.72

Table 1.1: Sine wave oscilloscope reading from the hard-copy, 0V offset

The voltage in the multimeter in V_{AC} and V_{DC} range are then recorded from the multimeter, and the values obtained are shown in the table below.

V_AC_rms(in V)	V_DC_rms(in V)	V_(AC+DC)_rms(in V)
0.707	-0.047	0.7085

Table 1.2: Voltage measurements from multimeter for in V_{AC}, V_{DC}, and V_{AC+DC}.

Afterward, the DC offset of the wave is set to 1V.

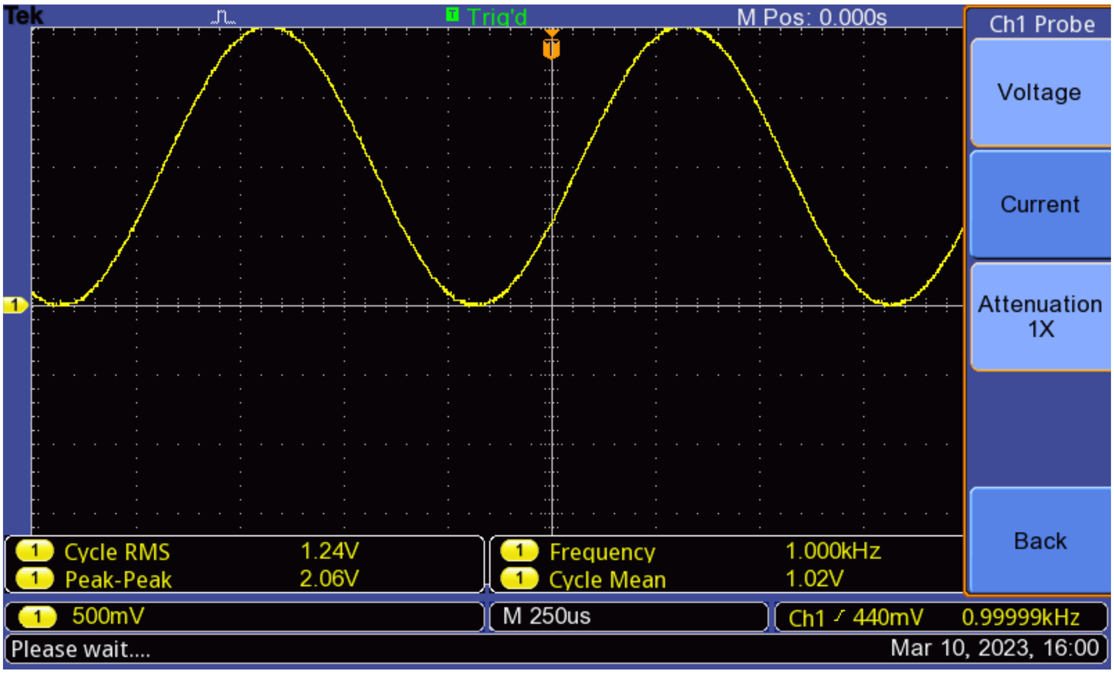

Figure 1.2: The Oscilloscope Hard-Copy view of the Sine wave with a DC offset of 1V

The values are recorded once more, on the oscilloscope and the multimeter.

V_pp(in V)	V_mean(in V)	V_rms(in V)
2.06	1.02	1.24

Table 1.3: The peak-to-peak voltage, the mean voltage, and the RMS voltage of the 1V DC-offset sine wave.

V_AC_rms(in V)	V_DC_rms(in V)	V_(AC+DC)_rms(in V)
0.706	1.001	1.228

Table 1.4: The AC, DC, and AC+DC RMS voltages recorded on the multimeter.

Preparation 2:
The setup remains the same, however now we use the exponential fall function, and the same data-gathering practice as in execution 1 applies.

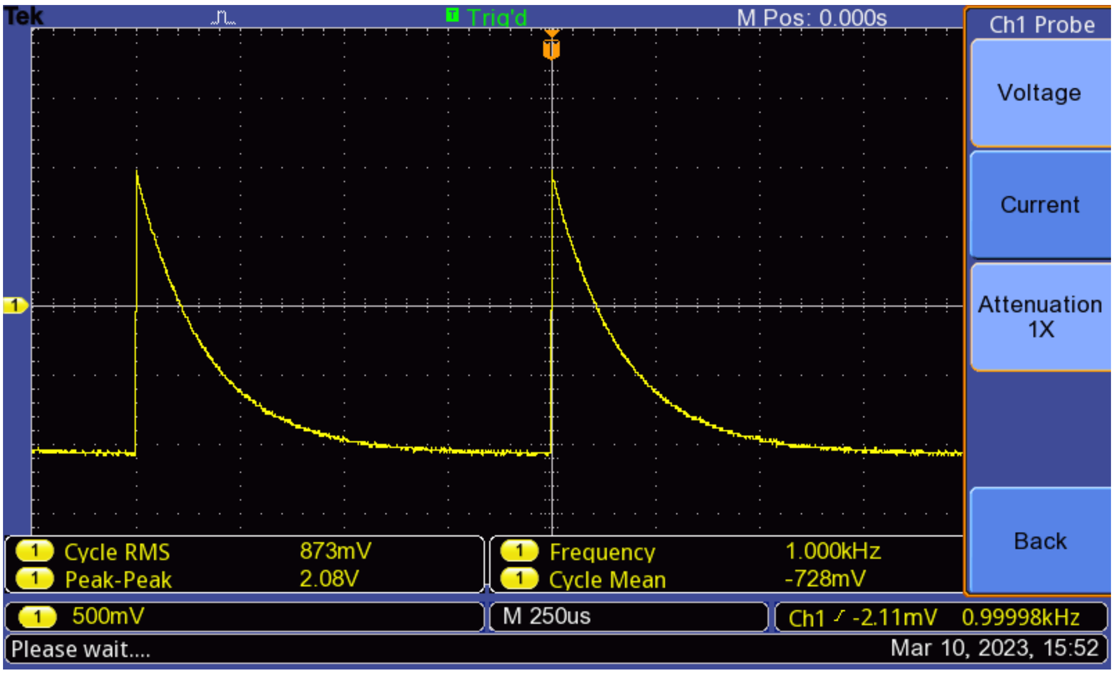

Figure 1.3: The hard copy of the exponential fall wave with an offset of 0V.

V_pp(in V)	V_mean(in V)	V_rms(in V)
2.08	-0.728	0.873

Table 1.5: The peak-to-peak voltage, the mean, and the RMS voltage measured from the hard copy.

The multimeter measurements:

V_AC_rms(in V)	V_DC_rms(in V)	V_(AC+DC)_rms(in V)
0.473	-0.718	0.857

Table 1.6: The AC, DC, and AC+DC RMS voltages obtained from the multimeter.

After the 1V offset is applied, the oscilloscope's hard-copy shows Figure 1.4:

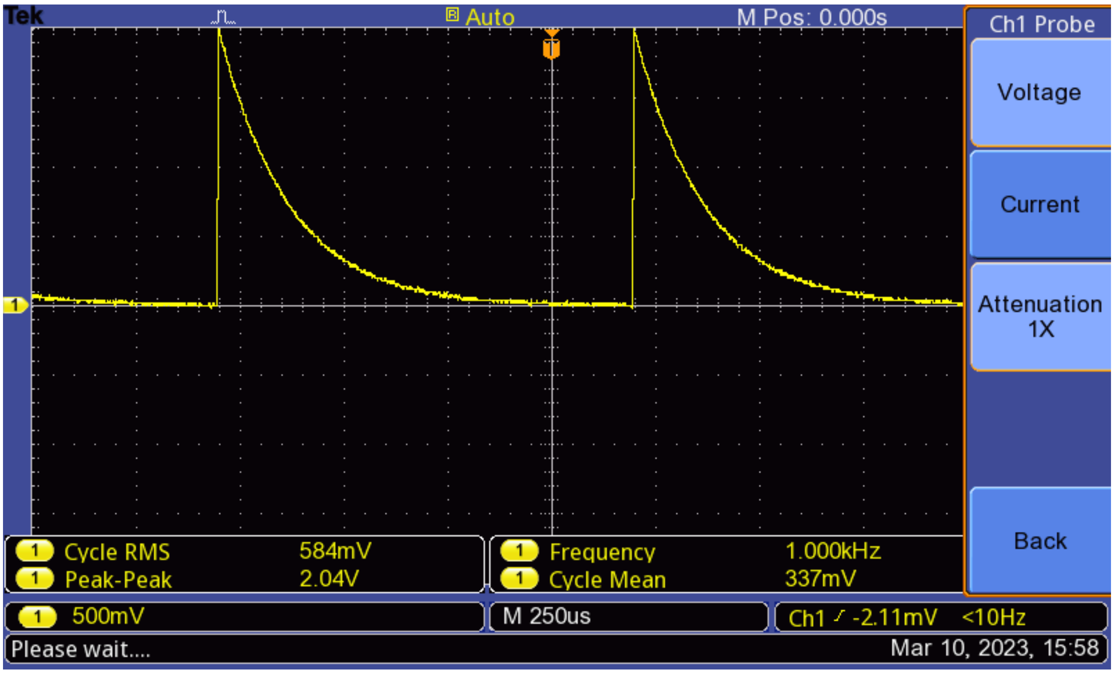

Figure 1.4: The hard copy of the exponential fall wave with a DC offset of 1V.

V_pp(in V)	V_mean(in V)	V_rms(in V)
2.04	0.337	0.584

Table 1.7: The voltage peak, mean, and the RMS obtained from the oscilloscope hard copy for the exponential fall wave with a 1V offset.

V_AC_rms(in V)	V_DC_rms(in V)	V_(AC+DC)_rms(in V)
0.471	0.33	0.576

Table 1.8: The AC, DC, and AC+DC RMS obtained for the exponential fall wave with a 1V offset using the multimeter.

Part 2: Measure AC Circuit Properties

Tools and Equipment:
TEKTRONIX TBS1072B Oscilloscope, TENMA multimeter, Function generator, ELABO multimeter

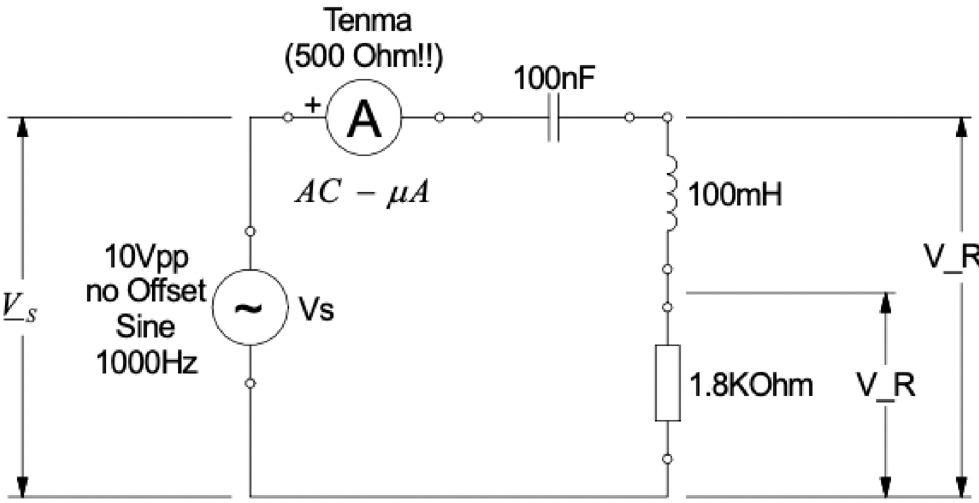

Figure 2.1: The circuit that is assembled.

The circuit depicted above is a simple RCL circuit that will be analyzed using the oscilloscope. A 100nF capacitor, a 100mH inductor, and a 1.8KOhm resistor are arranged. The reactance and resistance are then measured by the RLC meter. The values for the reactance and resistance are as follows for each component:

C_p:	96.57nF
R_p:	455.21kOhm
L_s:	101.52mH
R_s:	393.56Ohm
R:	1791.8Ohm

Table 2.1: The resistance and reactance values that are measured. R is the resistance in ohms measured at the multimeter, R_s is the added resistance of the inductor(which is in series to the actual inductor), and R_p is the added resistance of the capacitor(which is in parallel to the actual capacitor)

Execution

The phasor current is recorded from the TENMA multimeter in uA range.

Phasor_Current(uA)	Phasor_Current(uA) (in deg)
1223.4	21.9

Table 2.2: The phasor current measured from the TENMA multimeter.

The total phasor $I_S = 1.2234\angle 21.9^{\circ}$

Afterward, the V_R, V_S, V_{RL} phasor voltages are measured on the ELABO multimeter.

Phasor_Voltage(V_S) (in V)	Phasor_Voltage(V_R) (in V)	Phasor_Voltage(V_RL) (in V)
3.503	2.22	2.81

Table 2.3: The phasor voltages measured on the ELABO multimeter.

Afterward, the complete phasors are measured in the oscilloscope using the measure function. The phase change is shown in the oscilloscope hard copy as well.

Figure 2.2: The phasor voltage V_R shown on the oscilloscope.

The above figure shows the phasor voltage V_R.

Phasor_Voltage(V_R) (in V)	Phase_Voltage(V_R) (in deg)
2.22	21.9

Table 2.4: The phasor V_R's voltage and phase shift.

The phasor V_R is then $V_R = 2.22\angle 21.9^{\circ}$

Afterward, we view the phasor voltage V_{RL} on the oscilloscope.

Figure 2.3: The phasor voltage V_{RL} shown on the oscilloscope.

Phasor_Voltage(V_RL) (in V)	Phase_Voltage(V_RL) (in deg)
2.81	38.1

Table 2.5: The phasor V_{RL}'s voltage and phase shift.

The phasor V_{RL} is therefore

$$V_{RL} = 2.81\angle 38.1^{\circ}$$

The hardcopies for the voltage over the resistor and inductor, and the voltage over the resistor were obtained from another group due to methodical error by which we used the wrong resistor.

3 Evaluation

Part 1: Measure AC-Signal Properties

To calculate the mean voltage for the sine wave, we use the arithmetic mean formula:

$$\overline{v} = \frac{1}{T}\int_0^T v(t)dt \qquad \text{where } v(t) = \hat{v}\, sin(\omega t) + v_{off}$$

Evaluating the integral,

$$\begin{aligned}
\overline{v} &= \frac{1}{T}\int_0^T \hat{v}\, sin(\omega t) + v_{off} dt \\
&= \frac{1}{T}\left(\hat{v}\int_0^T sin(\omega t)\, dt + v_{off}\int_0^T dt\right) \\
&= \frac{1}{T}\left(\hat{v}\frac{1}{\omega}\left[- cos(\omega T)\right]_0^T + v_{off}T\right) \\
&= \frac{1}{T}\left(\frac{\hat{v}(-cos(\omega T)+1)}{\omega} + v_{off}T\right) \\
&= \frac{\hat{v}(-cos(\omega T)+1)+\omega T v_{off}}{\omega T}
\end{aligned}$$

For an offset of 0V:

$\omega = 2000\pi$ $(by\ virtue\ of\ 2pi \cdot f)$, $T = 1/1000$, $f = 1000\ Hz$, $\hat{v} = 2.06V$

$$\overline{v} = \frac{2.06(-cos(2000\pi*1/1000)+1)}{2000\pi*1/1000} = 0$$

This makes sense because the signal has no DC component, but this is also geometrically visible.

To calculate the RMS voltage, we use the RMS formula, which is defined

as $V = \sqrt{\frac{1}{T}\int_{t_0}^{t_0+T} v(t)^2 dt}$ where $v(t) = \hat{v}\, sin(\omega t) + v_{off}$

which leaves $V = \sqrt{\frac{1}{T} \int_{t_0}^{t_0+T} (\hat{v}\, sin(\omega t) + v_{off})^2 dt}$

When evaluated, we have:

$$V = \sqrt{\frac{1}{T}\left[\hat{v}^2 \left(\frac{1}{2}T - \frac{1}{4\omega} sin(2\omega t)\right) + 2\hat{v} \cdot v_{off}\left(-\frac{1}{\omega} cos(\omega T) + \frac{1}{\omega}\right)\right] + v_{off}^{\ 2} \cdot T}$$

$$= \sqrt{\frac{\hat{v}^2}{2} + \frac{2\hat{v} \cdot v_{off}\left(-\frac{1}{\omega} cos(\omega T) + \frac{1}{\omega}\right)}{T} + v_{off}^{\ 2}}$$

For 0V offset:

$$V = \sqrt{\frac{\hat{v}^2}{2}}$$
$$= \sqrt{\frac{(2.06/2)^2}{2}}$$
$$= 0.7283V$$

For 1V offset:

$$V = \sqrt{\frac{\hat{v}^2}{2} + \frac{2\hat{v} \cdot v_{off}\left(-\frac{1}{\omega} cos(\omega T) + \frac{1}{\omega}\right)}{T} + v_{off}^{\ 2}}$$
$$= \sqrt{\frac{(2.06/2)^2}{2} + \frac{2(2.06/2)(-\frac{1}{2000\pi} cos(1000\pi + \frac{1}{2000\pi})}{1/1000} + 1}$$
$$= 1.237V$$

The integral evaluated with a period T of 1/1000(derived from the fact that f=1000Hz, therefore T=(1/1000)s) gives us a value of 0.7283 volts at an offset of 0, and when evaluated with an offset of 1, gives us an RMS of 1.237.

V_mean(in V)	V_rms(in V)	Offset(in V)
0	0.7283	0
1	1.237	1

Table 3.1: The mean and RMS values, calculated for offsets of the sine wave at 1V and 0V.

To calculate the mean voltage for the exponential fall wave, we use the arithmetic mean formula:

$$\overline{v} = \frac{1}{T}\int_0^T v(t)dt \qquad \text{where } v(t) = \hat{v}\,(2e^{kt} - 1) + v_{off}$$

To evaluate the integral,

$$\overline{v} = \frac{1}{T}\int_0^T v(t)dt$$

$$= \frac{1}{T}\left(\int_0^T \hat{v}(2e^{kt} - 1)\,dt + \int_0^T V_{off}\,dt\right)$$

$$= \frac{1}{T}\left(\hat{v}\int_0^T 2e^{kt}dt - \int_0^T 1\,dt + \int_0^T V_{off}\,dt\right)$$

$$= \frac{\hat{v}\left(2(\frac{e^{kT}-1}{k})-T\right)+V_{off}T}{T}$$

For the exponential fall wave, the k value is found using the hard-copy CSV file of the oscilloscope export. Using the trendline, we find that $k =- 6037$.

Alternatively, to find the coefficient k, we can take the average over samples using a simple algebraic expansion where:

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

Taking the log of both sides,

$$kt = ln(\frac{v(t)-v_{off}}{2\hat{v}} + \frac{1}{2})$$

And dividing by time, we get

$$k = \frac{ln(\frac{v(t)-v_{off}}{2\hat{v}} + \frac{1}{2})}{t}$$

To calculate the RMS voltage, we use the RMS formula, which is defined as $V = \sqrt{\frac{1}{T}\int_{t_0}^{t_0+T} v(t)^2 dt}$ where $v(t) = \hat{v}\,(2e^{kt} - 1) + v_{off}$

which leaves $V = \sqrt{\frac{1}{T}\int_0^T (\hat{v}\,(e^{kt} - 1) + v_{off})^2 dt}$

When evaluated,

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

$$= \sqrt{\frac{1}{T}\int_0^T \hat{v}^2\,(4e^{2kt} - 4e^{kt} + 1)\,dt + \int_0^T 2\hat{v}(2e^{kt} - 1)v_{off}\,dt + \int_0^T {v_{off}}^2 dt}$$

$$= \sqrt{\frac{1}{T}\left[\hat{v}^2\left(\frac{2e^{2kT} - 4e^{kT} + 2}{T} + T\right) + 2\hat{v}v_{off}\left(\frac{2e^{kT} - 2}{k} - T\right) + {V_{off}}^2 T\right]}$$

The mean voltage for an offset of 0 is -0.689V, and the mean voltage for an offset of 1 is 0.310V. The RMS value for an offset of 0 is 0.843V and for an offset of 0V it is 0.576V.

V_mean(in V)	V_rms(in V)	Offset(in V)
-0.689	0.843	0
0.310	0.576	1

Table 3.2: The mean and RMS values, calculated for offsets of the exponential fall wave at 1V and 0V.

To find the V_{RMS} values, we use the formula $V_{RMS} = \sqrt{{V_{AC}}^2 + {V_{DC}}^2}$.

The following table shows the evaluation of this formula for each AC and DC RMS pair from the TENMA multimeter and its respective offset.

Sine Wave:				
V_AC_RMS(in V)	V_DC_RMS(in V)	V_RMS(in V)	Offset(in V)	V_(AC+DC)_rms_measured(in V)
0.707	-0.047	0.70856	0	0.7085
0.706	1.001	1.225	1	1.228
Exponential Fall:				
V_AC_RMS(in V)	V_DC_RMS(in V)	V_RMS(in V)	Offset(in V)	V_(AC+DC)_rms_measured(in V)
0.473	-0.726	0.8665	0	0.857
0.471	0.33	0.5751	1	0.576

Table 3.3: The RMS values for the sine and exponential fall waves, using the RMS formula for a superimposed DC value on an AC signal. The AC+DC measured value from the TENMA measure mode is also shown.

Sine Wave:					
V_RMS(in V)	V_RMS_Calculated(in V)	V_Mean(in V)	V_Mean_Calculated(in V)	V_PP(in V)	Offset(in V)
0.72	0.7283	-0.045	0	2.06	0
1.24	1.23711	1.02	1	2.06	1
Exponential Fall:					
V_RMS(in V)	V_RMS_Calculated(in V)	V_Mean(in V)	V_Mean_Calculated(in V)	V_PP(in V)	Offset(in V)
0.872	0.843	-0.726	-0.709	2.06	0
0.586	0.576	0.337	0.291	2.06	1

Table 3.4: The measured values for the exponential fall and sine wave signals.

The error in the RMS values for the exponential fall signal is largely due to the k coefficient.
Other error sources may be due to the multimeter's internal resistance, and the oscilloscope's attenuation in some cases.

Part 2: Measure AC Circuit Properties

The nominal impedances are as follows:

$Z_{AM} = 500\Omega$

$Z_C = 1/(j\omega C + 1/R) = 1/(j2000\pi \cdot 9.657 \cdot 10^{-8}F + 1/(455.21 \cdot 10^{3}\Omega)) = 1648.068\angle - 89^{\circ}$

$Z_L = j\omega L + 393.56 = j2000\pi \cdot 0.10152H + 393.56 = 749.5107\angle 58.3257^{\circ}$

$Z_R = 1791.8\Omega$

$Z_T = Z_{AM} + Z_C + Z_L + Z_R = 2874.6686\angle - 20.5736^{\circ}$

To find the peak current, we divide the nominal voltage source value by the total impedance. We know that V=10Vpp, so:

$I_S = (10\angle 0)/(2874.6686\angle - 20.5736^{\circ}) = 0.0034787\angle 20.5736\ A$

We can now calculate the nominal values using Ohm's law, $V = IZ$ where Z is an impedance.

$$V_R = I_S Z_R$$
$$V_L = I_L Z_R$$
$$V_C = I_S Z_C$$
$$V_{RL} = I_S (Z_R + Z_L)$$
$$V_{AM} = I_S Z_{AM}$$

And generally, we know that for RMS for a simple sinusoid(which is what we have fed through the circuit) we have $V_{RMS} = V_{PP}/2\sqrt{2}$.

	Nominal With Measured Impedance	
	Peak To Peak	**RMS**
I_S(in A)	0.0034787∠20.5736	0.0012299∠20.5736
V_S(in V)	10∠0	3.5355∠0
V_R(in V)	6.2331∠20.5736	2.2037∠20.5736
V_RL(in V)	7.9193∠36.8452	2.7999∠36.8452
V_L(in V)	2.6073∠78.8993	0.92182∠78.8993
V_C(in V)	5.7331∠-69.219	2.0269∠-69.219
V_AM(in V)	1.7393∠20.5736	0.61495∠20.5736
Z_R(in Ohm)	1791.8∠0	
Z_AM(in Ohm)	500∠0	
Z_L(in Ohm)	749.5107∠58.3257	
Z_C(in Ohm)	1648.0677∠-89.7926	

Table 3.5: The nominal voltages calculated by using the measured impedance values from the RLC meter. The Zs are the measured impedances.

As we can see, the values are close to the nominal values. However, it must be noted that the RLC meter itself does add an error to the measurements' values.

Further, we determine the voltages over each element using the measured current and measured voltage. We obtain the voltage over the capacitor and the inductor from the measured V_RL, V_S, V_R and V_AM(which is obtained using the current and the theoretical impedance of the ammeter, about 500 Ohm) using KVL, where

$$V_C = V_S - V_{AM} - V_{RL}$$
$$V_L = V_S - V_{AM} - V_C - V_R$$

Then each impedance is found using Ohm’s law, where we have

$$Z_R = V_R/I_S$$
$$Z_C = V_C/I_S$$
$$Z_L = V_L/I_S$$
$$Z_{AM} = V_{AM}/I_S$$

	Determined With Measured Voltage & Current	
	Peak To Peak	**RMS**
I_S(in A)	0.0034603∠21.9	0.0012299∠20.5736
V_S(in V)	9.908∠0	3.503∠0
V_R(in V)	6.2791∠21.9	2.22∠21.9
V_RL(in V)	7.9479∠38.1	2.81∠38.1
V_L(in V)	2.5977∠80.5058	0.91842∠80.5058
V_C(in V)	5.9154∠-69.7416	2.0914∠-69.7416
V_AM(in V)	1.7301∠21.9	0.6117∠21.9
Z_R(in Ohm)	1814.615∠0	
Z_AM(in Ohm)	500∠0	
Z_L(in Ohm)	750.7096∠58.6058	
Z_C(in Ohm)	1709.4978∠-91.6416	

Table 3.6: The voltages determined from the measured voltage values(namely V_C and V_L determined from V_RL, V_R and V_S), and their theoretical impedance values determined from the measured current using Ohm’s Law.

To calculate the element values of the capacitor and inductor(to get them in the RLC meter form) we set their rectangular form representation to equal to the way we obtain them. For the inductor,

$$a + jb = j\omega L + R$$
where $a = R,\ b = \omega L$, so $L = b/\omega$

and for the capacitor

$1/(a + jb) = j\omega C + 1/R$, and taking the conjugate:
$$a/(a^2 + b^2) - jb/(a^2 + b^2) = j\omega C + 1/R$$
Which leads to $R = (a^2 + b^2)/a,\ C = -b/(\omega(a^2 + b^2))$

Using these formulas, we can now obtain the parallel resistance of the capacitor, the series resistance of the inductor, and the capacitor's actual value along the inductor's actual value. The table below describes all of these properties.

		Measured	Calculated
Z_C	R_P(in ohm)	4.55E+05	5.88E+04
	C_P(in nF)	9.66E-08	9.31E-08
	R(in ohm)	5.9667	5.95
	jX(in ohm)	-1648.0569	-1708.7962
Z_L	R_S(in ohm)	393.56	391.062
	L_S(in mH)	101.52	101.99
	R(in ohm)	393.56	391.062
	jX(in ohm)	637.869	640.8084
Z_R	R(in ohm)	1791.8	1814.615
	jX(in ohm)	0	0

Table 3.7: The measured and calculated parallel resistance of the capacitor, the capacitance, the reactance and resistance obtained from the rectangular form, and the measured and calculated series resistance of the inductor, the inductivity, and the reactance and resistance obtained from its rectangular form. The resistor impedance is also shown.

We notice a methodical error in how the value of the resistor in parallel to the capacitor is obtained. The formula provided above to obtain the resistor in parallel to the capacitor works for nominal values, however, it does seem to give the wrong result for the calculated values. This may be because of the error between the voltage and phase of the measured voltage over the capacitor and the nominal voltage and phase over the capacitor.

	Nominal With Measured Impedance		Determined With Measured Voltage & Current	
	Peak To Peak	**RMS**	**Peak To Peak**	**RMS**
I_S(in A)	0.0034787∠20.5736	0.0012299∠20.5736	0.0034603∠21.9	0.0012299∠20.5736
V_S(in V)	10∠0	3.5355∠0	9.908∠0	3.503∠0
V_R(in V)	6.2331∠20.5736	2.2037∠20.5736	6.2791∠21.9	2.22∠21.9
V_RL(in V)	7.9193∠36.8452	2.7999∠36.8452	7.9479∠38.1	2.81∠38.1
V_L(in V)	2.6073∠78.8993	0.92182∠78.8993	2.5977∠80.5058	0.91842∠80.5058
V_C(in V)	5.7331∠-69.219	2.0269∠-69.219	5.9154∠-69.7416	2.0914∠-69.7416
V_AM(in V)	1.7393∠20.5736	0.61495∠20.5736	1.7301∠21.9	0.6117∠21.9
Z_R(in Ohm)	1791.8∠0		1814.615∠0	
Z_AM(in Ohm)	500∠0		500∠0	
Z_L(in Ohm)	749.5107∠58.3257		750.7096∠58.6058	
Z_C(in Ohm)	1648.0677∠-89.7926		1709.4978∠-91.6416	
RLC Meter				
		Measured	**Calculated**	
Z_C	**R_P(in ohm)**	4.55E+05	5.88E+04	
	C_P(in nF)	9.66E-08	9.31E-08	
	R(in ohm)	5.9667	5.95	
	jX(in ohm)	-1648.0569	-1708.7962	
Z_L	**R_S(in ohm)**	393.56	391.062	
	L_S(in mH)	101.52	101.99	
	R(in ohm)	393.56	391.062	
	jX(in ohm)	637.869	640.8084	
Z_R	**R(in ohm)**	1791.8	1814.615	
	jX(in ohm)	0	0	

Table 3.8: All measured and calculated values.

Most of the errors come down to the RLC meter's inaccuracy, and the oscilloscope's inaccuracy as well. Some of the data was obtained from other groups, as it seems that during the experiment we had a methodical error by which we used the wrong resistor for the experiment, and it caused our voltage over the capacitor, resistor, and the inductor to be drastically different from the nominal values. That is the reason why the hard-copy provided for the second part of the evaluation is not from the same Oscilloscope as for the first part of the evaluation, where there was no such methodical error.

Furthermore, the calculated resistance component over the capacitor seems to have been obtained incorrectly. This may be because of the difference between the nominal voltage of the capacitor and the measured value.

We notice, however, for the most part that the nominal values are very closed to their measured counterparts, and the derived ones as well(namely the voltage over the capacitor and the voltage over the inductor).

4 Conclusion

In this experiment, we determined that we can analyze AC signals in a variety of ways, mainly using the oscilloscope, however finding that even the multimeter may be handy in times when the frequency is low. It was observed that the oscilloscope is extremely useful in displaying the signals generated by the function generator, and the measure function was used in conjunction with the multimeter to analyze the RMS voltage and the peak-to-peak voltage.

Furthermore, we analyzed the phase-shift effect that reactive components such as capacitors and inductors have on circuits with the sinusoidal wave we fed through the simple RCL circuit. The RLC meter was used to read the values of the inductor and the capacitor.

In the first part, we see very minor error which may be caused by the inaccuracy of the Oscilloscope. There is no methodical error here, and the measured values are very close to the nominal ones.

In the second part, however, we had a methodical error when setting up the experiment, where we seem to have used the wrong resistor. For this reason, we have obtained some of the oscilloscope hard-copy(photos) from another group. We also notice an error in the calculated value for the resistor in parallel to the capacitor. Overall, the measured and calculated values are very close to each other excluding the resistor in parallel to the capacitor.

5 References

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6. Google sheets