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Constructor University Bremen

Natural Science Laboratory

Electrical Engineering II

Spring Semester 2024

Lab Experiment 2- AC Properties and Measurements

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Place of execution: Teaching Lab EE

Rotation II, Bench 12

Date of execution: 01 March, 2024

1.INTRODUCTION

Understanding the behavior of alternating current (AC) signals and the properties of alternating current (AC) circuits is fundamental in electrical engineering. This experiment aimed to explore the characteristics of alternating current (AC) signals and the behavior of simple AC circuits through experimentation and analysis.

2.THEORY

Periodic Signals

A periodic signal is a type of waveform that repeats its pattern over time within a defined interval, known as a period. In essence, it's a signal that exhibits a cyclic behavior, where the same sequence of values recurs at regular intervals. These intervals are consistent and predictable. It is described by the equation

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

Where $v(t)$ might be any periodic function e.g. a sin, n is an integer number and T is the time of one period. From T we can determine the frequency f**.** That is how many times per second this sequence is repeated. It is described by the equation

$$f = \frac{1}{T} = \frac{1}{s} = 1Hz \quad \text{Hz=(Hertz)}$$

An example of a signal function is $v(t) = \hat{u}\, sin\omega t$ where $\hat{u}$ is the peak value of the wave or amplitude. Mostly f and T are time properties of the wave functions.

The effects of a function over a period of time is called **Arithmetic Mean Value** and is described by the equation

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

where $\bar{v}$ is the mean value of a voltage. However, without DC their mean is zero!

Root Mean Square Value

To make electrical quantities for signals like power comparable to each other a second value was defined, the root mean square value, it can be determined using specialized devices such as oscilloscopes and multimeters. The signal qualities can be obtained using oscilloscopes and used to calculate the RMS or the measure function. For a multimeter, take measurements in the DC range first, then the AC range, and then use the following calculation. All currents and voltages with the same RMS value put the same energy over time into a load, in other words, they have the same power . For DC holds

$$W = VIt = RI^2t = \frac{V^2}{R}t$$

If u and i is time dependent for short time dt

$$dW = vidt = Ri^2dt = \frac{v^2}{R}dt$$

The energy is calculated by integration. The resistor needs to be constant as a pre-condition

$$W = \int_0^t vidt = R\int_0^t i^2dt = \frac{1}{R}\int_0^t v^2dt$$

If this should be comparable to the DC case following conditions must hold

$$\int_0^t i^2dt = I^2T \qquad \int_0^{t0+T} v^2dt = V^2T$$

The integral and the multiplication will calculate the same area under the function.Dividing the equation by the period T and taking the square root over the whole function will calculate V or I from the function as root mean square (rms) value

$$I = \sqrt{\frac{1}{T}\int_{t0}^{t0+T} i^2 dt} \qquad V = \sqrt{\frac{1}{T}\int_{t0}^{t0+T} v^2 dt}$$

What happens in case of a periodic function superimposed by a DC value? The equation for the current may be rearranged in the following way

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

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 by

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

The previous calculations all apply for the calculations of voltages. To calculate AC properties, the Kirchoff’s rules KCL and KVL still apply. The sum of currents flowing into that node is equal to the sum of currents flowing out of that node and the directed sum of the electrical potential differences around any closed circuit must be zero respectively.

3. EXECUTION

Experiment Setup
Workbench No.12

Used tools and instruments:
Breadboard, Tools box from workbench, Multimeters TENMA and ELABO, Generator, Oscilloscope, BNC Cable, BNC T-connector, BNC-Banana

Experiment Part 1 – Setup
Measuring AC-Signal Properties

Objective
Our goal was to determine the characteristics of exponential and periodic AC signals.

Preparation 1
We connected the generator, oscilloscope and multimeter using a BNC cable, BNC- T-connector, and the BNC-Banana connector with some lab wires. Then terminated the whole chain with a 50Ω resistor at the multimeter. The initial settings for the generator were as follows:

Function = Triangle('Ramp' for Agilent 33220A generator)
Symmetry = 0%(because we used a generator)
Frequency = 1kHz
Amplitude = set to $2V_{pp}$ (volts peak to peak) measured at the oscilloscope
Offset = 0V
Amplitude/ Offset setting results in a $\pm\ 1V$ wave

Execution and Results 1
Before taking the measurements we made sure that the V_{pp} was exactly 2V. We then went ahead with recording and taking the measurements of the V_{pp}, mean value and root mean square value with the oscilloscope using the measure functions **RMS Cycle** and **Mean Cycle** and also took hard-copies as proof of what we were doing. We later recorded the voltage with the multimeter in V_{AC} and V_{DC} range, and then directly measured the combined AC+DC RMS value using the TENMA by pressing the yellow 'AC+DC' button. We repeated the process above, but this time we changed the DC offset of the wave to 1V, making sure that the resulting wave moved between ground (=0V) and 2V

Results

DC Offset = 0

V_{pp}(V) oscilloscope	Vmean(V) oscilloscope	V_{RMS}(V) oscilloscope	V_{AC}(V) TENMA	V_{DC} (V) TENMA	V_{AC}+ V_{DC} (v) TENMA
2.04V	-0.00628	0.588	0.5758	0.00015	0.577

Table 1, with DC Offset=0

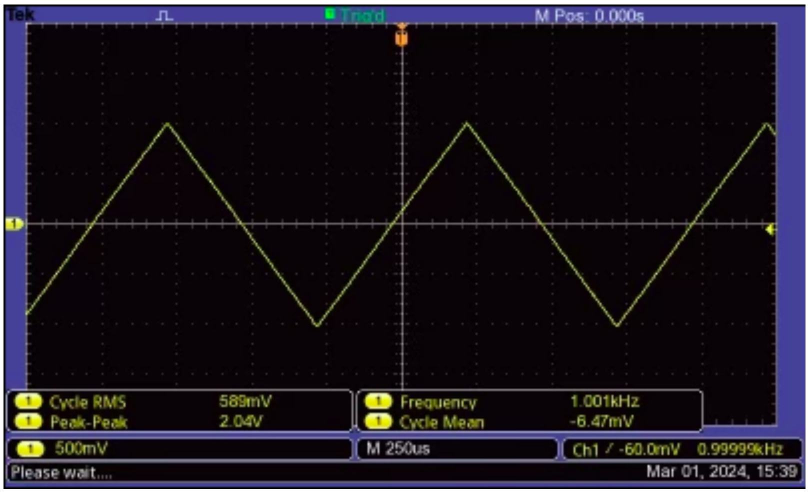

Figure 1

DC Offset = 1

V_{pp}(V) oscilloscope	Vmean(V) oscilloscope	V_{RMS}(V) oscilloscope	V_{AC}(V) TENMA	V_{DC} (V) TENMA	V_{AC}+ V_{DC} (v) TENMA
2.02	1.17	1.02	0.5747	0.9907	1.1485

Table 2, with DC Offset=1

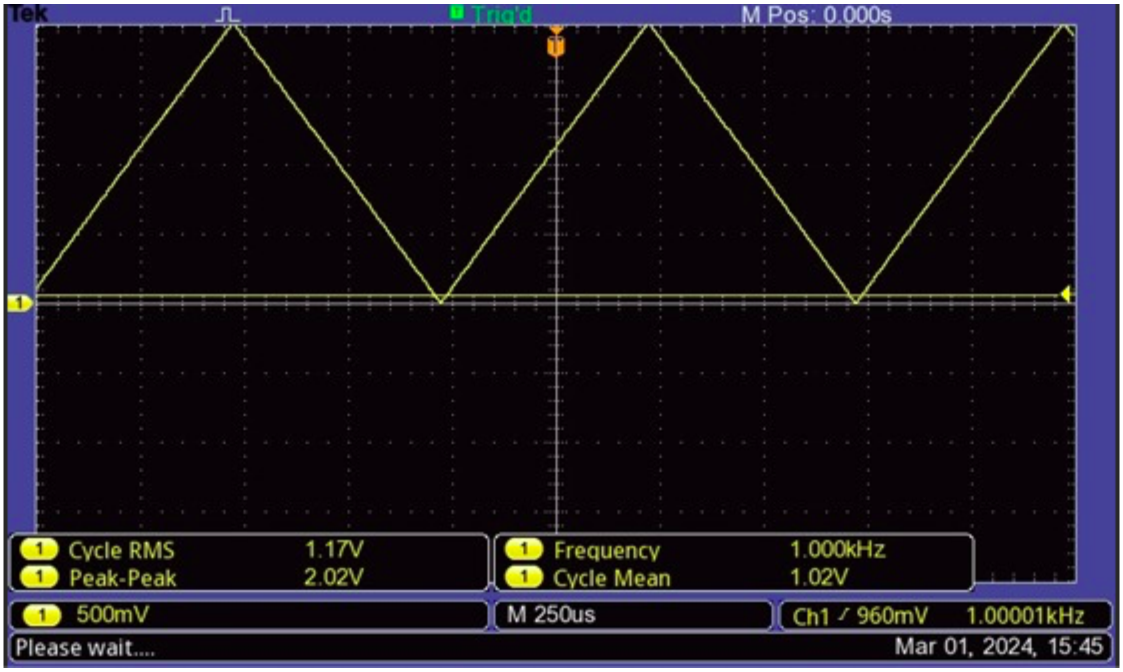

Figure 2

Preparation 2

For this part we left the setup as it was in preparation 1 and only changed the generator settings as follows:

Function = Arb - select 'Exp rise' in generator menu
Frequency = 1kHz
Amplitude = set to $2V_{pp}$ (volts peak to peak) measured at the oscilloscope
Offset = 0V
Amplitude/ Offset setting results in a $\pm\ 1V$ wave

Execution and Results 2
We repeated the execution from **Execution 1**, but this time with a different generator setting**!**

Results

DC Offset=0

V_{pp}(V) oscilloscope	Vmean(V) oscilloscope	V_{RMS}(V) oscilloscope	V_{AC}(V) TENMA	V_{DC} (V) TENMA	V_{AC}+ V_{DC} (v) TENMA
2.04	0.68	0.835	0.5026	0.6729	0.8209

Table 3, with DC Offset=0

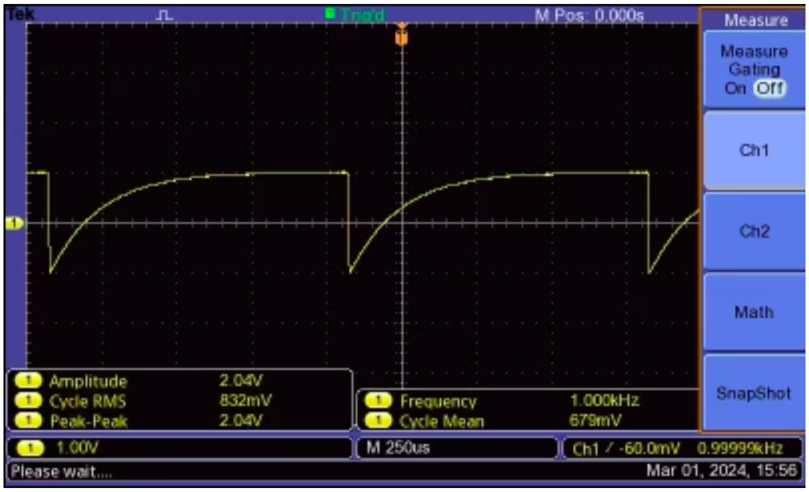

Figure 3

DC Offset=1

V_{pp}(V) oscilloscope	Vmean(V) oscilloscope	V_{RMS}(V) oscilloscope	V_{AC}(V) TENMA	V_{DC} (V) TENMA	V_{AC}+ V_{DC} (v) TENMA
2.02	1.70	1.76	0.4711	1.6624	1.7277

Table 4, with DC Offset=1

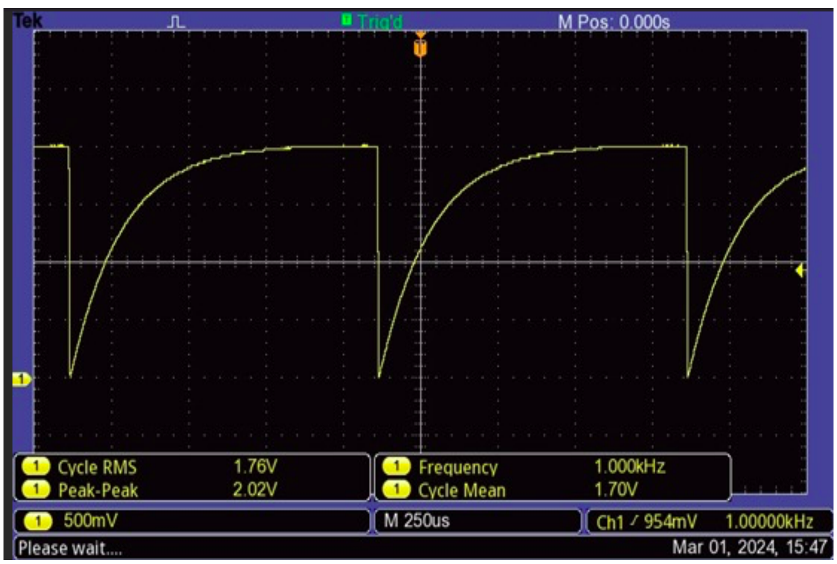

Figure 4

Experiment Part 2 – Setup
Measuring AC Circuit Properties

Objective
Our goal was to measure the voltage, current and element values of components of a circuit.
Preparation
We first measured the impedance and element values of the inductor and capacitor at 1KHz using the RLC meter. We used the series substitute circuit for the inductor and the parallel substitute circuit for the capacitor. We later used the Elabo multimeter to determine the exact value of the resistance. After taking all the measurements and recording them, we then assembled the circuit below on the breadboard. All the measurements for the inductor, capacitor and resistor are summarized in table 5.

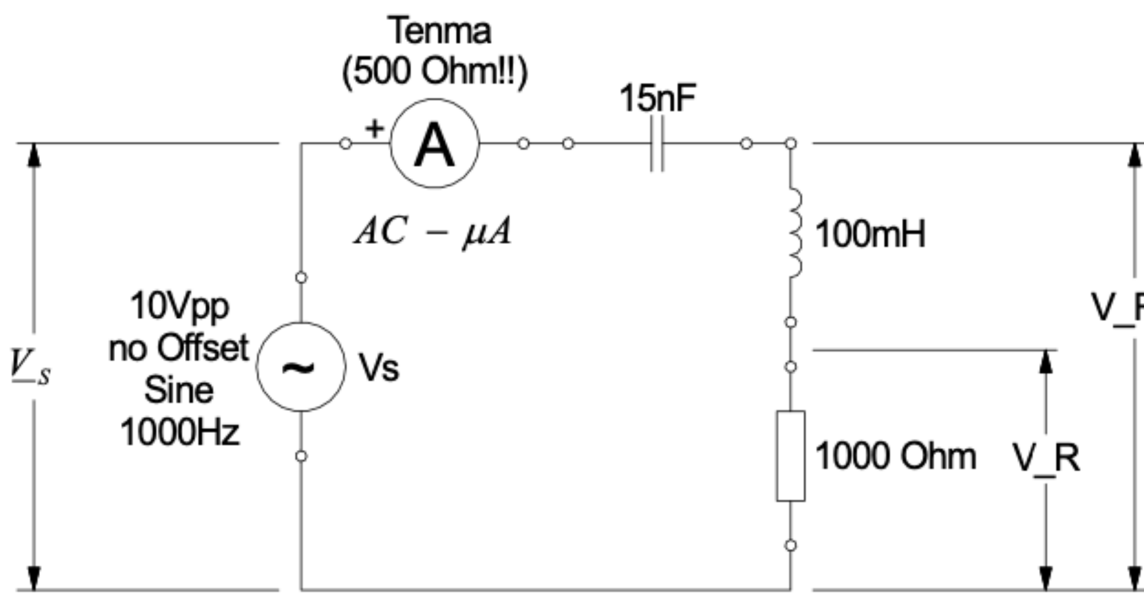

Figure 5

Table of values and impedances

Resistor	Inductor (Series)	Capacitor (Parallel)
1KΩ	101.30mH	15.228nF
-	392.89Ω	2.7960MΩ

Table 5

Execution and Results

For all measurements $\hat{v}_s = 5V \angle 0^o$ was the reference signal. Before recording the values we verified that the amplitude was correct. We first measured the phaser current from the TENMA multimeter by setting it to AC and range μA and the value was 355.32 μA. Thereafter the Elabo multimeter with range

20V was connected across the terminals of the generator to measure the phasers across V_S, the resistor V_R and V_{RL} across the inductor and the resistor and the values were as follows in table 6.

Phaser Voltage

Vs(V)	V_R(V)	V_{RL}(V)
3.582	0.383	0.587

Table 6

To get the complete phaser of V_R, V_{RL}, and I, we measured the phases with the oscilloscope. We Connected channel 1 to V_S, with our reference phase $\angle 0^\circ$. We then Connected the second signal to channel 2. To get the phase we used the measure function of the oscilloscope. Source channel was CH1 and the function was Phase CH1-CH2. The resistor did not have any phase change because the current that goes through it is the same. All measurements are summarized in table 7.

Complete Phaser

V_R(V)	V_{RL}(V)	I(μA)
0.353	0.5441	352.83
$0.353\angle 79.2^o$	$0.5441\angle 100^o$	$352.83\angle 79.2^o$

Table 7

4.EVALUATION

Part 1: Measuring AC-Signal Properties

Calculating the theoretical $\overline{v}$ and V of the Triangle wave for offset 0 V and 1 V, we use the following formula implemented in the generator:

$$V = f(t) = \frac{4\hat{u}}{T}t + \hat{u} + u_{off} \quad : -\frac{T}{2} \le t \le 0 \text{.........(i)}$$

$$V = f(t) = -\frac{4\hat{u}}{T}t + \hat{u} + u_{off} \quad : 0 \le t \le \frac{T}{2} \text{........(ii)}$$

When offset is 0

To get $\overline{v}$, we use the formula below:

$$\overline{v} = \frac{1}{T}\left[\int_{\frac{-T}{2}}^{0} (\frac{4\hat{u}}{T}t + \hat{u} + u_{off})dt + \int_{0}^{\frac{T}{2}} (-\frac{4\hat{u}}{T}t + \hat{u} + u_{off})dt\right]$$

$$\overline{v} = \frac{1}{T}\left[\left[\frac{2\hat{u}}{T}t^2 + \hat{u}t + u_{off}t\right]_{\frac{-T}{2}}^{0} + \left[-\frac{2\hat{u}}{T}t^2 + \hat{u}t + u_{off}t\right]_{0}^{\frac{T}{2}}\right]$$

$$\overline{v} = \frac{1}{T}\left[-\left[(\frac{2\hat{u}}{T}(\frac{-T}{2})^2 + \hat{u}(\frac{-T}{2}) + u_{off}(\frac{-T}{2})\right] + \left[-\frac{2\hat{u}}{T}(\frac{T}{2})^2 + \hat{u}(\frac{T}{2}) + u_{off}(\frac{T}{2})\right]\right]$$

$$\overline{v} = \frac{1}{T}(u_{off}T)$$

$$\overline{v} = u_{off}$$

Now calculating the the theoretical $\overline{v}$ of the triangle wave

When offset is 0:

$$\overline{v} = u_{off}$$

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

When offset is 1:

$$\overline{v} = u_{off}$$

$$\overline{v} = 1V$$

To get V, we use the formula below:

$$V = \sqrt{\frac{1}{T}\left[\int_{\frac{-T}{2}}^{0}(\frac{4\hat{u}}{T}t + \hat{u} + u_{off})^2 dt + \int_{0}^{\frac{T}{2}}(-\frac{4\hat{u}}{T}t + \hat{u} + u_{off})^2 dt\right]}$$

$$V = \sqrt{\frac{1}{T}\left[\int_{\frac{-T}{2}}^{0}(\frac{16\hat{u}^2}{T^2}t^2 + \frac{8\hat{u}^2}{T}t + \frac{8\hat{u}}{T}u_{off}t + \hat{u}^2 + 2\hat{u}u_{off} + u_{off}^2)\ dt + \int_{0}^{\frac{T}{2}}(\frac{16\hat{u}^2}{T^2}t^2 - \frac{8\hat{u}^2}{T}t - \frac{8\hat{u}}{T}u_{off}t + \hat{u}^2 + 2\hat{u}u_{off} + u_{off}^2)\ dt\right]}$$

$$V = \sqrt{\frac{1}{T}\left[\left[\frac{16\hat{u}^2}{3T^2}t^3 + \frac{4\hat{u}^2}{T}t^2 + \frac{4\hat{u}}{T}u_{off}t^2 + \hat{u}^2 t + 2\hat{u}u_{off}t + u_{off}^2 t\right]_{-\frac{T}{2}}^{0} + \left[\frac{16\hat{u}^2}{3T^2}t^3 - \frac{4\hat{u}^2}{T}t^2 - \frac{44}{T}u_{off}t^2 + \hat{u}^2 t + 2\hat{u}u_{off}t + u_{off}^2 t\right]_{0}^{\frac{T}{2}}\right]}$$

$$V = \sqrt{\frac{1}{T}\left[-(\frac{16\hat{u}^2}{3T^2}(-\frac{T}{2})^3 + \frac{4\hat{u}^2}{T}(-\frac{T}{2})^2 + \frac{4\hat{u}}{T}u_{off}(-\frac{T}{2})^2 + \hat{u}^2(-\frac{T}{2}) + 2\hat{u}u_{off}(-\frac{T}{2}) + u_{off}^2(-\frac{T}{2})) + (\frac{16\hat{u}^2}{3T^2}(\frac{T}{2})^3 - \frac{4\hat{u}^2}{T}(\frac{T}{2})^2 - \frac{4}{T}u_{off}(\frac{T}{2})^2 + \hat{u}^2(\frac{T}{2}) + 2\hat{u}u_{off}(\frac{T}{2}) + u_{off}^2(\frac{T}{2})\right]}$$

$$V = \sqrt{\frac{1}{T}(\frac{4\hat{u}^2}{3}T - 2\hat{u}^2 T - 2\hat{u}u_{off}T + \hat{u}^2 T + 2\hat{u}u_{off}T + u_{off}^2 T)}$$

$$V = \sqrt{\frac{4\hat{u}^2}{3} - \hat{u}^2 + u_{off}^2}$$

Now calculating the the theoretical V of the triangle wave

When offset is 0:

$$V = \sqrt{\frac{4\hat{u}^2}{3} - \hat{u}^2 + u_{off}^2}$$

$$V = \sqrt{\frac{4(2.04)^2}{3} - (2.04)^2 + (0)^2}$$

$$V = 0.577V$$

When offset is 1:

$$V = \sqrt{\frac{4\hat{u}^2}{3} - \hat{u}^2 + u_{off}^2}$$

$$V = \sqrt{\frac{4(2.02)^2}{3} - (2.02)^2 + (1)^2}$$

$$V = 1.54V$$

To calculate the theoretical $\bar{v}$and V of the Exponential Rise wave for offset 0 V and 1 V, the following formula implemented in the generator was used

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

To find the constant k, we make kt the subject of the formula and we get

While V=y

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

$kt = ln(\frac{1}{2} - \frac{0-0}{2*2.04})$

Graphing the above function using random values to get the constant value k we get:

$k = ln(\frac{1}{2} - \frac{0}{2*2.04})/t,\ where\ t = 1.125 * 10^{-4}s$

$k = ln(\frac{1}{2} - \frac{0}{2*2.04})/1.125 * 10^{-4}$

$k =- 6161.3$

When offset is 0

$\bar{v} = \frac{1}{T}\int_{t0}^{t0+T} v(t)dt,\ where\ v(t) = f(t)$

$\bar{v} = \frac{1}{T}\int_{t0}^{t0+T} \hat{v}(1 - 2e^{-6161.3t}) + v_{off}$

$\bar{v} = \frac{1}{T}\int_{t0}^{t0+T} \hat{v} - 2\hat{v}e^{-6161.3t} + v_{off}$

$\bar{v} = \frac{1}{T}(\hat{v}T - \frac{\hat{v}e^{-6161.3T}}{3465.74} + v_{off}T)$

$\bar{v} = 2.04 - \frac{\hat{v}e^{-6161.3T}}{3465.74T} + 0$

$\bar{v} = 0.845V$

When offset is 1

$\bar{v} = \frac{1}{T}\int_{t0}^{t0+T} v(t)dt,\ where\ v(t) = f(t)$

$\bar{v} = \frac{1}{T}\int_{t0}^{t0+T} \hat{v}(1 - 2e^{-6161.3t}) + v_{off}$

$\bar{v} = \frac{1}{T}\int_{t0}^{t0+T} \hat{v} - 2\hat{v}e^{-6161.3t} + v_{off}$

$$\bar{v} = \frac{1}{T}\left(\hat{v}T - \frac{\hat{v}e^{-6161.3T}}{3465.74} + v_{off}T\right)$$

$$\bar{v} = 2.02 - \frac{\hat{v}e^{-6161.3T}}{3465.74T} + 1$$

$$\bar{v} = 1.67V$$

Now calculating the the theoretical V of the triangle wave

$$V = \sqrt{\frac{1}{T}\int_{t0}^{t0+T}\left(\hat{v} - 2\hat{v}e^{-6161.3t} + v_{off}\right)^2}$$

$$V = \sqrt{\frac{1}{T}\int_{t0}^{t0+T}\left(\hat{v} - 2\hat{v}e^{-6161.3t} + v_{off}\right)\left(\hat{v} - 2\hat{v}e^{-6161.3t} + v_{off}\right)}$$

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

$$V = \sqrt{\hat{v}^2 - \frac{4}{Tk}\hat{v}^2e^{kT} + 2\hat{v}v_{off} + \frac{2}{Tk}\hat{v}^2e^{2kT} - \frac{4}{Tk}\hat{v}v_{off}e^{kt} + v_{off}{}^2}$$

When offset=0

$$V = \sqrt{(2.04)^2 - \frac{4}{T(-6161.3)}(2.04)^2e^{(-6161.3)T} + 2(2.04)(0) + \frac{2}{T(-6161.3)}(2.04)^2e^{2(-6161.3)T} - \frac{4}{T(-6161.3)}(0)(2.04) + (0)^2}$$

$$V = 0.82V$$

When offset=1

$$V = \sqrt{(2.04)^2 - \frac{4}{T(-6161.3)}(2.04)^2e^{(-6161.3)T} + 2(2.04)(1) + \frac{2}{T(-6161.3)}(2.04)^2e^{2(-6161.3)T} - \frac{4}{T(-6161.3)}(2.04)(1) + (1)^2}$$

$$V = 1.73V$$

After focusing on the multimeter before pressing the yellow button we measured the voltage in AC and DC range separately, where the combination of both AC and DC voltage is VRMS and the DC voltage is the mean value.

So determining the V_{RMS} values using the V_{DC} and V_{AC} readings with and without the offset for both the triangle waves and exponential waves, we get

Triangle waves

Without offset

$$V_{RMS} = \sqrt{(V_{DC})^2 + (V_{AC})^2}$$

$$V_{RMS} = \sqrt{(0.00015)^2 + (0.5758)^2}$$
$$V_{RMS} = 0.5758000195V$$
$$V_{RMS} \approx 0.58V$$

With offset

$$V_{RMS} = \sqrt{(V_{DC})^2 + (V_{AC})^2}$$
$$V_{RMS} = \sqrt{(0.9907)^2 + (0.5747)^2}$$
$$V_{RMS} = 1.145323788V$$
$$V_{RMS} \approx 1.15V$$

Exponential waves
Without offset

$$V_{RMS} = \sqrt{(V_{DC})^2 + (V_{AC})^2}$$
$$V_{RMS} = \sqrt{(0.6729)^2 + (0.5026)^2}$$
$$V_{RMS} = 0.8398816405V$$
$$V_{RMS} \approx 0.84V$$

With offset

$$V_{RMS} = \sqrt{(V_{DC})^2 + (V_{AC})^2}$$
$$V_{RMS} = \sqrt{(1.6624)^2 + (0.4711)^2}$$
$$V_{RMS} = 1.727862544V$$
$$V_{RMS} \approx 1.73V$$

Comparing the calculated voltage values to the actual readings on the TENMA in the AC+DC measure mode, we can confirm that the values are almost the same!This is summarized in table 8.

	V_{AC}+ V_{DC} (v) TENMA	V_{RMS}(V) Theoretical
Triangle wave without offset	0.577	0.5758
Triangle wave with offset 1	1.1485	1.1453
Exponential wave without offset	0.8209	0.83988
Exponential wave with offset	1.7277	1.72786

Table 8

Signal Shape	Triangle Wave					
Offset	0V			1V		
	Vpp(V)	Vmean(V)	Vrms(V)	Vpp(V)	Vmean(V)	Vrms(V)
Oscilloscope	2.04	-0.00628	0.588	2.02	1.02	1.17
Tenma		0.00015	0.577		0.9907	1.1485
Calculated (integral)		0	0.577		1	1.54
Calculated (Formula)			0.58			1.15

Table 9: Showing a compiled table for all measured and calculated values of the Triangle wave

Signal Shape	Exponential Rise					
Offset	0V			1V		
	Vpp(V)	Vmean(V)	Vrms(V)	Vpp(V)	Vmean(V)	Vrms(V)
Oscilloscope	2.04	0.68	0.84	2.02	1.70	1.76
Tenma		0.67	0.82		1.66	1.73
Calculated (integral)		0.85	0.82		1.67	1.73
Calculated (Formula)			0.84			1.73

Table 10: Showing a compiled table for all measured and calculated values of the Exponential Rise

According to the tables above, the mean values of the oscilloscope signals differ from the theoretical values in that they are bigger. This mistake is caused by the internal resistance as well as the horizontal and vertical precision. It is also attributable to the method used to obtain the k constant. Because it does not span a wide range of the graph, using a random point reduces the chances of receiving the true number. Another reason for the disparity in mean values is that the oscilloscope may have detected noise in the signal. The V_{RMS} values received from the oscilloscope and the Tenma multimeter and the values computed from the Tenma's AC and DC components, differ slightly from the theoretical values. However, because of the inaccuracies indicated above in the oscilloscope, the pairs of values received from the Tenma are more accurate than the values from the oscilloscope. The mistakes in the Tenma values are due to the resistance that might have been raised on the wires of the circuit.

Part 2: Measuring AC Circuit Properties

To Calculate all $\hat{i}$ and $\hat{v}$ values using the nominal input voltage $\hat{v}_s = 5V \angle 0^o$ and the measured impedance values from the RLC meter, we do the following:

Let TENMA resistance = TR

$TR = 500\Omega$

Below are the readings we got from the RLC meter.

$Cp = 15.23 * 10^{-9}F$

$R_C = 2.81 * 10^{6}\Omega$

$Ls = 101.3 * 10^{-3}H$

$R_L = 392.89\Omega$

$R = 1000$

$Z_C = R_c + \frac{1}{j\omega C}$, where ω is $\frac{2\pi}{T} = 6283.19$

$\frac{1}{Z_C} = \frac{1}{R_c} + j\omega C$

$\frac{1}{Z_C} = \frac{1}{2.81*10^6} + j6283.19 * 15.23 * 10^{-9}$

$\frac{1}{Z_C} = \frac{1+j268.897}{2810000}$

$Z_C = \frac{2810000}{1+j268.90} * \frac{1-j268.90}{1-j268.90}$

$Z_C = \frac{2810000-j755601368.6}{72306.597}$

$Z_C = 38.86 - j10449.96\Omega$

$Z_L = R_L + j\omega L, where\ \omega\ is\ \frac{2\pi}{T} = 6283.19$

$Z_L = 397.89 + j6283.19 * 101.3 * 10^{-3}\Omega$

$Z_L = 397.89 + j636.49\Omega$

Calculating the total impedances at the 1kΩ resistor for the inductor and the capacitor is

$Z_r = R + Z_L + Z_C + Z_{TR}$

$Z_r = 1000 + 397.89 + j636.49 + 38.86 - j10449.96 + 500$

$Z_r = 1936.75 - j9813.47\Omega$

And since they are all in series, to get the current $\hat{i}$, we use ohms law. To make our calculations easier, we convert from rectangular form to phasor form using the formula $z = r\angle\theta$, where r is $\sqrt{x^2 + y^2}$, (where the x axis represents the real part and the y axis represents the imaginary part of a complex number.) and θ is Arctan of $\frac{y}{x}$.

$r = 10002.76$

$\theta = -78.84$

$Z_r = 10002.76\angle - 78.84^o$

To calculate the current, we use ohms law

$\hat{i} = \frac{\hat{v}}{R}$

$\hat{i} = \frac{5\angle 0^o}{10002.76\angle -78.84^o}$

$\hat{i} = 4.999 * 10^{-4}\angle 78.84^o A$

Now that we have the current, we can go ahead and calculate the all $\hat{v}$ values in our circuit, using ohms law.

TENMA Voltage

$\hat{v}_{TR} = \hat{i}Z_{TR}$

$\hat{v}_{TR} = 4.999 * 10^{-4}\angle 78.84^o * 500,\ we\ can\ convert\ the\ TENMA\ impedance\ to\ phasor\ form$

$\hat{v}_{TR} = 4.999 * 10^{-4}\angle 78.84^o * 500\angle 0^o$

$\hat{v}_{TR} = 0.25\angle 78.84^o V$

Capacitor Voltage

$\hat{v}_C = \hat{i}Z_C$

$\hat{v}_C = 4.999 * 10^{-4}\angle 78.84^o * 38.86 - j10449.96\Omega,$ *we can convert the capacitor impedance to phasor form*

$\hat{v}_C = 4.999 * 10^{-4}\angle 78.84^o * 10450.03\angle - 89.79^o$

$\hat{v}_C = 5.22\angle - 10.95^o V$

Inductor Voltage

$\hat{v}_L = \hat{i}Z_L$

$\hat{v}_L = 4.999 * 10^{-4}\angle 78.84^o * 397.89 + j636.49,$
we can convert the inductor impedance to phasor form, for easy calculations

$\hat{v}_L = 4.999 * 10^{-4}\angle 78.84^o * 750.62\angle 57.99^o$

$\hat{v}_L = 0.38\angle 136.83^o V$

1KΩ Resistor Voltage

$\hat{v}_R = \hat{i}R$

$\hat{v}_R = 4.999 * 10^{-4}\angle 78.84^o * 1000,$
we can convert the $1k\Omega$ *Resistor impedance to phasor form, for easy calculations*

$\hat{v}_R = 4.999 * 10^{-4}\angle 78.84^o * 1000\angle 0^o$

$\hat{v}_R = 0.50\angle 78.84^o V$

Now calculating $\hat{v}$ over every component in the circuit using the measured voltage and current values we get

$\hat{v}_R = 0.353\angle 79.2^o V$ which is $(0.07 + j0.35)$V

$\hat{v}_{RL} = 0.5441\angle 100^o V$ which is (-0.09+j0.54)V

$\hat{v}_L = \hat{v}_{RL} - \hat{v}_R$

$\hat{v}_L = \; - 0.09 + j0.54 - (0.07 + j0.35)$

$\hat{v}_L = - 0.16 + j0.19$

$\hat{v}_{TR} = \hat{i} Z_{TR}$

$\hat{v}_{TR} = 3.52 * 10^{-4}\angle 79.2^o * 500\angle 0^o$

$\hat{v}_{TR} = 0.18\angle 79.2^o V$ which is (0.03+j0.18)V

$\hat{v}_C = \hat{v}_s - \hat{v}_R - \hat{v}_{TR} - \hat{v}_L$

$\hat{v}_C = 3.582 - (0.07 + j0.35) - (0.03 + j0.18) - (- 0.16 + j0.19)$

$\hat{v}_C = (3.642 - j0.72)V$

Name	Theoretical value	Measured Value
$\hat{v}_s$	$3.582\angle 0^o$V	$3.582\angle 0^o$V
$\hat{v}_R$	$0.50\angle 78.84^o$V	$0.353\angle 79.2^o$V
$\hat{v}_{TR}$	$0.25\angle 78.84^o$V	$0.18\angle 79.2^o V$
$\hat{v}_L$	$0.38\angle 136.83^o$V	$0.25\angle 130^o$V
$\hat{v}_C$	$5.22\angle -10.95^o$V	$3.71\angle -11.18^o$V
$\hat{i}$	$4.999 * 10^{-4}\angle 78.84^o$A	352.83∠79.2ºµA

you cannot really compare!! Theoretical values are amplitudes, measured are RMS!

Table 11: Showing a compiled table with all measured and calculated voltages and currents.

From the table above, the measured values column slightly differs from the theoretical values column. Additionally there are slight differences in the phase shifts too. One of the causes of the differences in the measurement is the Error propagation when converting the phasor form and complex form. Moreover the instrumental errors from the RLC meter. measurement of the element and resistance values of the capacitor and inductor using the RLC meter, oscilloscope and theTenma might have also contributed to the inaccuracy of values in the theoretical. This means that the slight difference in the measured values was caused by the instrumental errors.

Calculating the impedances using the measured values

$$Z_R = \frac{\hat{v}R}{\hat{i}}$$

$$Z_R = \frac{0.353\angle 79.2^o}{352.83*10^{-6}\angle 79.2}$$

$Z_R = 1000.48\angle 0^o\Omega$

$Z_L = \frac{\widehat{vL}}{\widehat{i}}$

$Z_L = (0.5441\angle 100^o - 0.353\angle 79.2^o)/352.83 * 10^{-6}\angle 79.2^o$

$Z_L = 703.18\angle 51.147^o\Omega$

$Z_{TR} = \frac{\widehat{vTR}}{\widehat{i}}$

$Z_{TR} = \frac{0.18\angle 79.2^o}{352.83*10^{-6}\angle 79.2^o}$

$Z_{TR} = 510.16\angle 0^o\Omega$

$Z_c = \frac{\widehat{VC}}{\widehat{i}}$

$Z_c = \frac{\widehat{v}_s - \widehat{v}_R - \widehat{v}_{TR} - \widehat{v}_L}{\widehat{i}}$

$Z_c = \frac{3.582\angle 0^o - 0.353\angle 79.2^o - (0.5441\angle 100^o - 0.353\angle 79.2^o) - 0.18\angle 79.2^o}{352.83*10^{-6}\angle 79.2^o}$

$Z_c = 10520.10\angle - 90.3^o$

Calculating the element Values :

Element value of capacitor:

$Z_c = 10520.10\angle - 90.3^o$, converting it to rectangular form

$Z_c =- 55.08 - j\,10519.96$, since the capacitor is in parallel with the resistor we get

$- j10519.96 = \frac{1}{j\omega C}$

$- j10519.96 = \frac{-j}{\omega C}$

$- j10519.96\omega C =- j$

$C = \frac{1}{10519.96\omega}, \omega = 2000\pi$

$C = \frac{1}{10519.96 \times 2000\pi}$

$C = 1.51 \times 10^{-8} F$

Element value of inductor:

$Z_L = 703.18\angle 51.147^o \Omega$, converting it to rectangular form

$Z_L = 441.12 + j\,547.61$

$j\,547.61 = j\omega L, \omega = 2000\pi$

$547.61 = 2000\pi L$

$L = 0.0872H$

	Measured	Calculated
C	$15.23 * 10^{-9} F$	$1.51 \times 10^{-8} F$
L	$101.3 * 10^{-3} H$	$0.0872H$
Zc	$38.86 - j10449.96\Omega$	-56.139-j10521.47
Zl	$397.89 + j636.49\Omega$	441.12+j547.61
Zr	1000+j0	1000.48+j0

Table 12:Showing a comparison of all measured and calculated element value

The calculated and measured values fall within a similar range. The differences observed can be attributed to significant phase shifts in the capacitor impedance. One possible reason for these substantial differences might stem from computational errors. Additionally, instrumental inaccuracies during measurements could have impacted the results. Hence, despite these discrepancies, measured values tend to be more accurate compared to calculated ones.

5. CONCLUSION

In conclusion, the multimeter proves to be more precise in measuring values compared to the oscilloscope due to its higher level of accuracy. However, when utilizing measurements obtained from both the oscilloscope and the Tenma multimeter, it's important to acknowledge the potential occurrence of errors. These errors may arise from factors such as the resistance introduced by additional wires and the interpretation of readings from graphical representations. AC signals and measurements pose unique challenges due to their time-varying nature. Impedance variations, phase shifts, and harmonic distortions can significantly affect the accuracy of measurements. Therefore, when conducting experiments involving AC signals, careful calibration of instruments and consideration of potential sources of error are essential for obtaining reliable data and drawing accurate conclusions.

6. REFERENCE

1. Pagel Uwe, General Electrical Engineering II Lab Manual (2024). Constructor University