Jacobs University Bremen

Electrical and Computer Engineering

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Lab Experiment 2 – AC Properties and Measurements

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1 Introduction

This week, we learned how to determine properties of AC-signals and measure and display the behavior of simple AC-circuits. We also learned how to operate a signal generator and use it to build an AC circuit with different components. Then, we learned to use an oscilloscope to take measurements from an AC circuit, and how to operate it in different scenarios to measure different entities like peak-to-peak voltage, V_{RMS}, phase difference, offset, amplitude etc. We also had a chance to analyze differences in properties of resistors, capacitors and inductors, and how they affect the phase and amplitude of a signal passing through.

1.1 Objective:

We have the following objectives for this experiment:

- understanding the properties, functions, and usage of an AC-signals
- determining the value of rms voltage for different types of waveforms.
- Measuring and display the behavior of simple AC-circuits.
- Learning to operate important tools like the signal generator and oscilloscope.

1.2 Theory:

1.2.1 The oscilloscope

An oscilloscope is an electronic test instrument that graphically displays varying signal voltages. Measurements on oscilloscopes are usually displayed as calibrated, two-dimensional plots of one or more signals as a function of time.

1.2.2 Kirchoff's Voltage Law:

Kirchhoff's Voltage Law states that, in any closed loop network, the total voltage around the loop is equal to the sum of all the voltage drops within the same loop. Hence, the algebraic sum of the voltage at a node in a closed loop of an electric circuit is zero.

1.2.3 Periodic Signal:

A periodic signal is one that repeats after a certain period of time. It is represented mathematically as follows:

$$v(t) = v(t + nt)$$

where, 'T' is time for one period for a periodic function '$v(T)$', and 'n' is any integer. The frequency of the signal is defined as:

$$f = \frac{1}{T} = 1\ Hz$$

1.2.4 Arithmetic Mean Value:

Within a given circuit, the average value of an AC is known as the Arithmetic Mean Value of an AC. The mean value of an AC is given by:

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

where, $v(t) = \hat{v} sin\omega t$, with $\hat{v}$ being the peak value of the wave. For alternating periodic signals without any DC component, the mean arithmetic value over time is zero.

1.2.5 Root Mean Square (RMS) Value:

RMS (voltage or current) refers to the steady state voltage or current which, when passed through a resistor, would produce the same amount of heat as the AC equivalent, while passing through the same resistor in the same interval of time. The RMS value of Voltage (V_{RMS}) is given by:

$$V_{RMS} = \sqrt{\frac{1}{T}\int_{t_o}^{t_o+T} v^2 dt}$$

But, for the readings of Multimeter, the value of V_{RMS} is calculated as:

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

Similarly, for Current (I), the formulae can be obtained by replacing V by I in the above equations.

2 Execution

2.1 Experimental set-up part 1:

We have required/used the following tools in the execution of our experiment:

- Agilent Signal Generator
- TEKTRONIX Oscilloscope
- TENMA Multimeter
- ELABO Multimeter
- BNC Cable, BNC T connector, BNC Banana Connector

2.1.1 Part 1: Setup:

On a breadboard, we connected the generator, the oscilloscope and a multimeter using a BNC cable, the BNC- T-connector, and the BNC-Banana connector with some lab wires. The initial settings for the generator are as follows:
The initial settings for the generator were set to the following:

Function	=	sine
Frequency	=	1kHz
Amplitude	=	set to 2 Vpp (measured at the oscilloscope)
Offset	=	0V

Amplitude/ Offset setting results in a $\pm 1V$ wave.

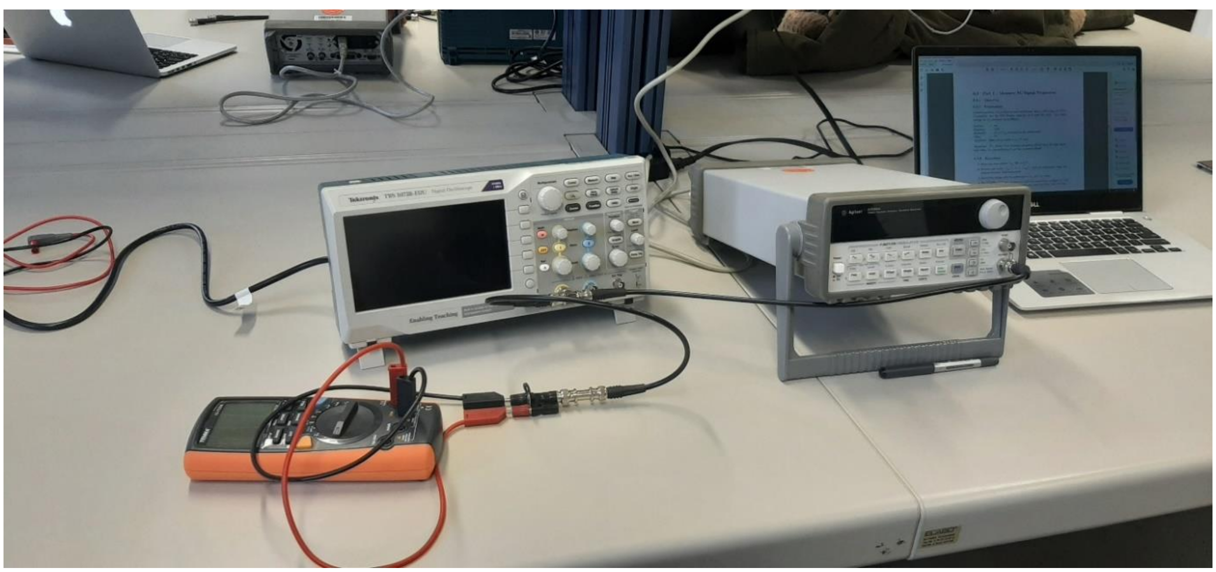


Fig 1: Experimental Setup for Part 1

2.1.2 Part 1-Execution and Results:

We checked if $V_{pp} = 2V$. Then, we measured $V_{pp}, \bar{v}, and\ V\ (V_{rms})$ with the oscilloscope using the measure function. Then, we measured the V_{AC}, V_{DC} and V_{AC+DC} for the same setup using the multimeter.

With Offset value = 0V, we obtained the following data:

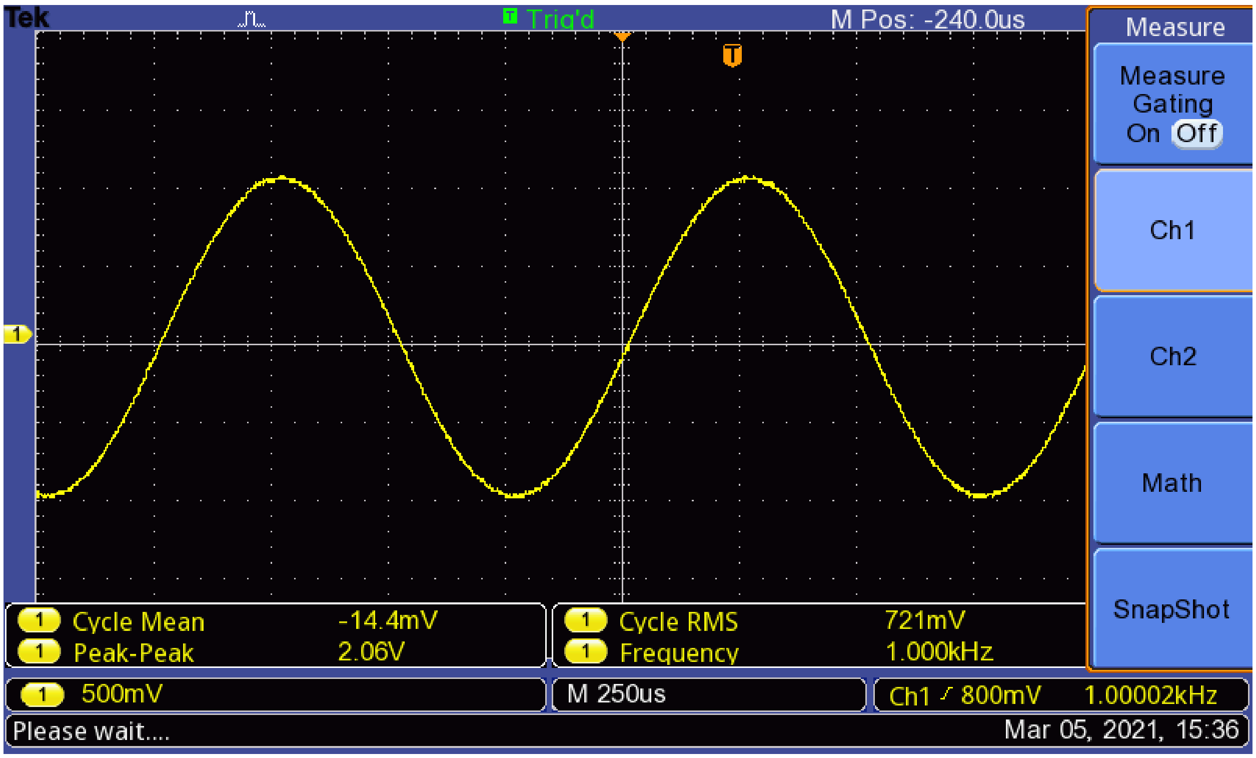


Fig 2. Voltage vs. Time for Offset = 0V

Then we used the oscilloscope to set the DC offset of the wave to 1V. Everything else remains the same. We followed the same procedure and take the same measurements as before. We obtained the following data:

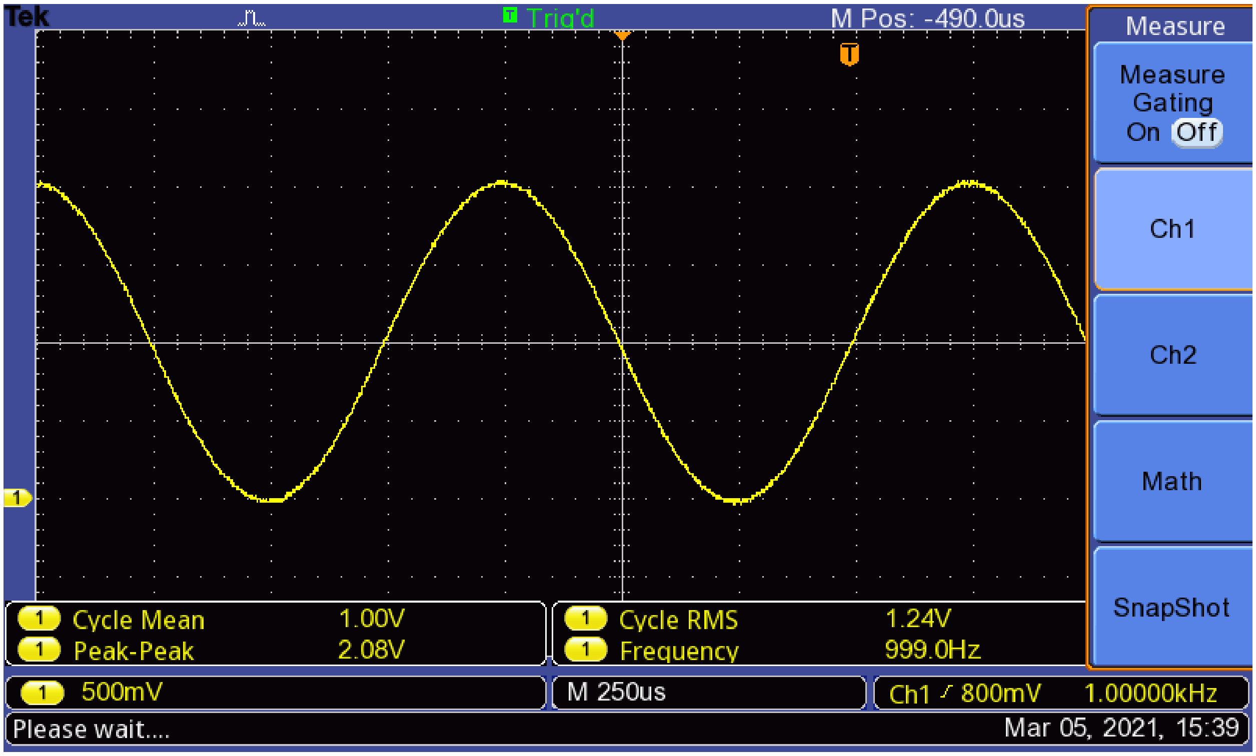


Fig 3: Voltage vs. Time for Offset = 1V

The results have been tabulated below:

Attribute\Wave	**1**	**2**
Function	Sine	Sine
Frequency	1kHz	1kHz
Amplitude [V]	2Vpp (approximate)	2Vpp(approximate)
Offset [V]	0V	1V
Vpp [V]	2.06 V	2.08V
$\overline{v}$ [V]	- 0.0144V	1.00V
V (Vrms) [V]	0.721V	1.24V
V_{DC} [V]	0V	0.9888V
V_{AC} [V]	0.7042V	0.7039V
V_{AC+DC} [V]	0.7048V	1.2092V

Table 1: List of attributes at different settings.

After completing the measurements for offset 0V and 1V for sine function, we changed the function to Exp_Fall and repeated the process. The following are the settings for the generator.

Function	=	Exp_Fall
Frequency	=	1kHz
Amplitude	=	set to 2Vpp (measured at the oscilloscope)
Offset	=	0V

These Amplitude/Offset settings result in a $\pm 1v$ wave.

By following the same procedure, we obtained the following data:

For Offset = 0, we have:

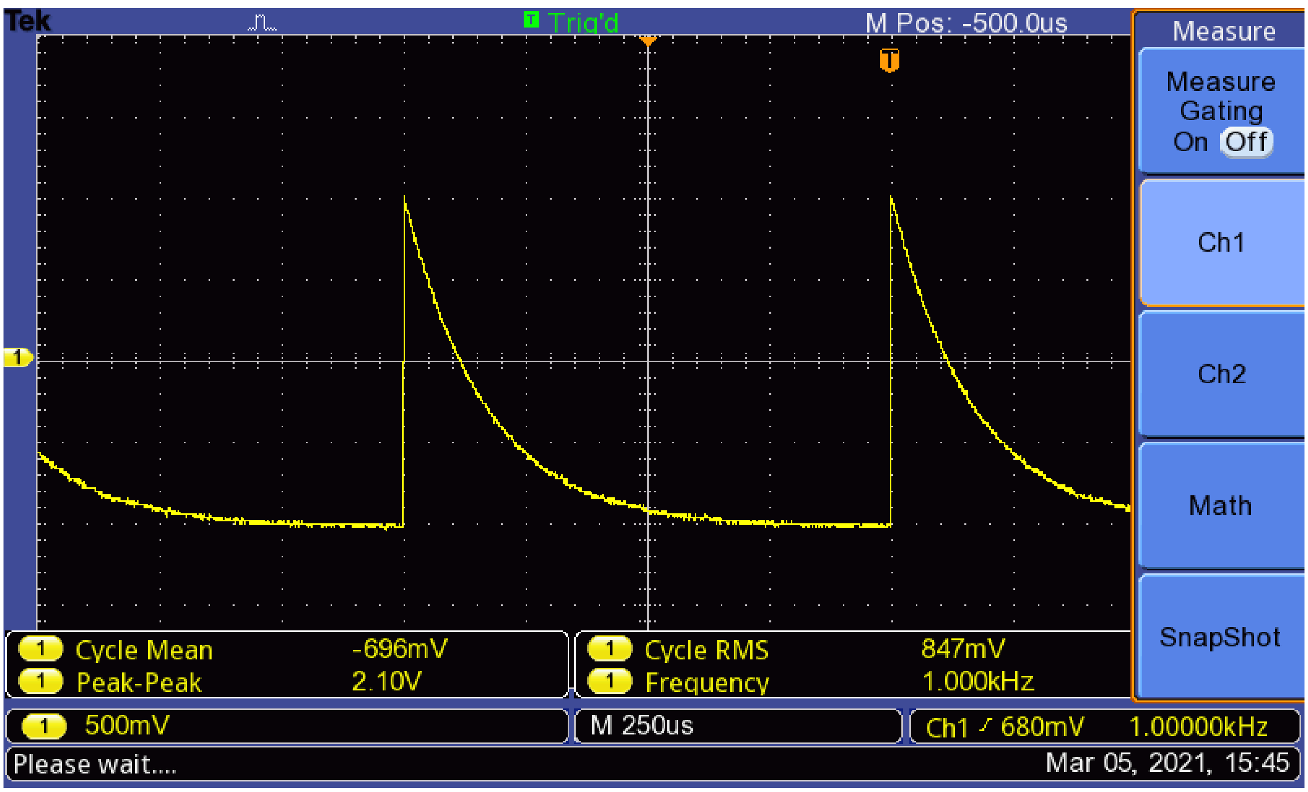


Fig 4: Voltage vs. Time for Offset 0V (Exp_Fall Function)

For Offset = 1, we have:

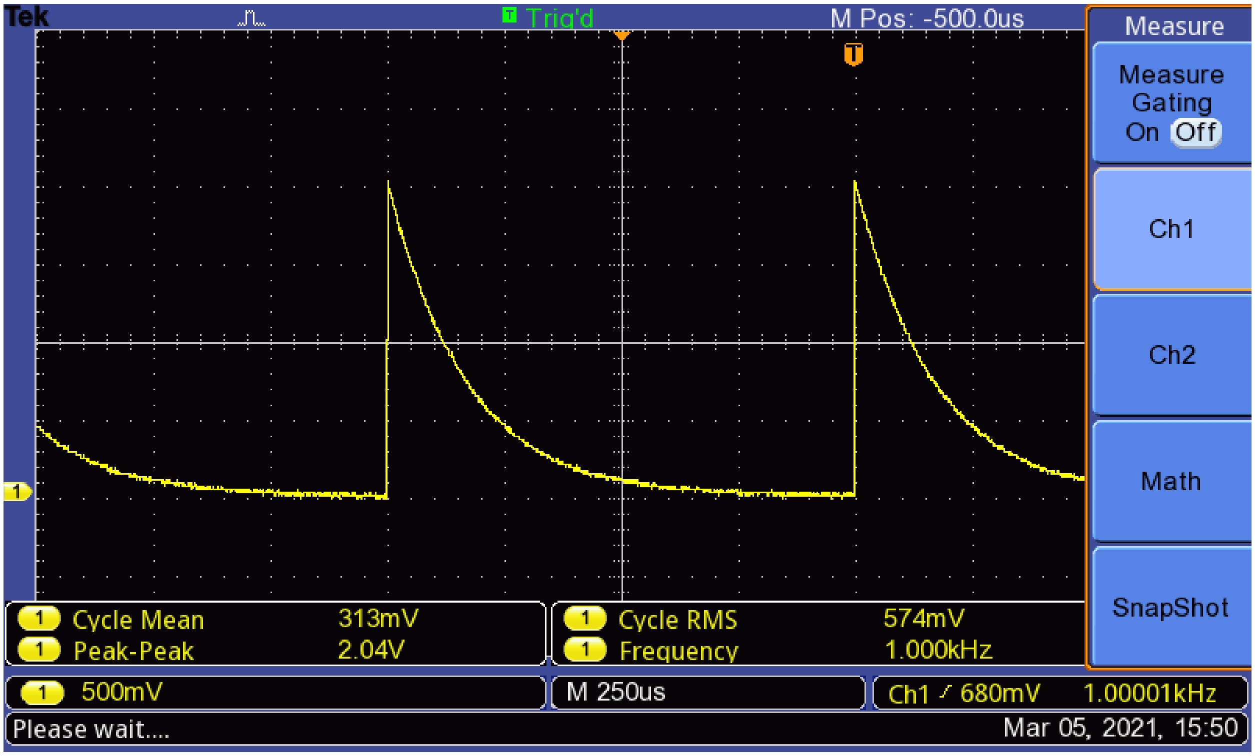


Fig 5: Voltage vs. Time for Offset 1V (Exp_Fall Function)

The following result is tabulated:

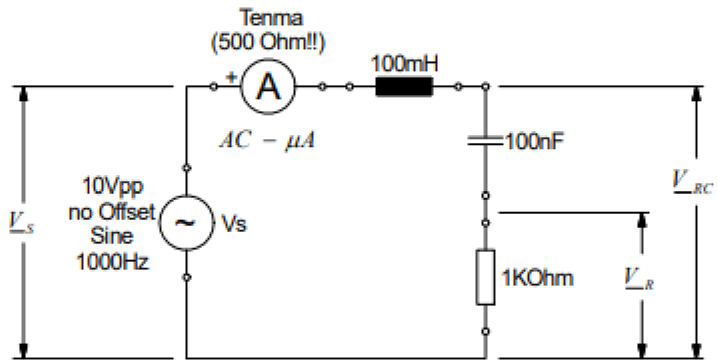
Attribute\Wave	**1**	**2**
Function	Exp_Fall	Exp_Fall
Frequency	1kHz	1kHz
Amplitude [V]	2Vpp (approximate)	2Vpp(approximate)
Offset [V]	0V	1V
Vpp [V]	2.10V	2.04V
$\overline{v}$ [V]	-0.696V	0.313V
V (Vrms) [V]	0.847V	0.574V
V_{DC} [V]	-0.6707V	0.3198V
V_{AC} [V]	0.4724V	0.4685V
V_{AC+DC} [V]	0.8232V	0.5625V

Table 2: List of attributes at different settings.

2.2 Part 2: Measure AC Circuit Properties:

2.2.1 Part 2- Setup:

For this part of the experiment, we used the following set-up:



2.2.2 Part 2- Execution

We found the components of the circuit in the experiment box and measured the impedance and the element values of the inductor and the capacitor at the 1kHz with the RLC meter in room 54. Pictures are provided below:

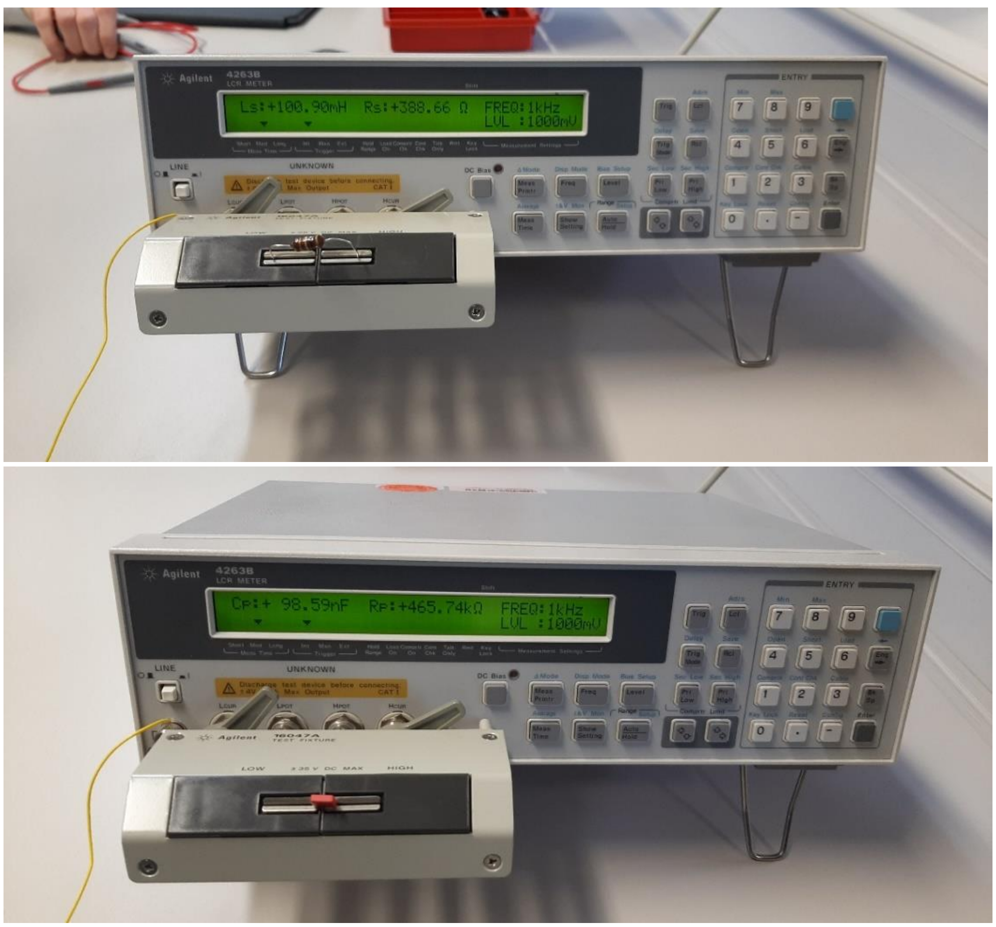


Fig 6: Use of RLC meter to measure capacitance and inductance

We measured the values for the resistor using the Elabo multimeter. The results are the following:

C_p = 98.59nF, L_s = 100.90 mH and R = 9932 Ω

Since the value of frequency is 1000 Hz, the value of angular frequency ω is 2000π.

For the capacitor:

C_p = 98.59 nF
R_p = 465.74 KΩ
Admittance of capacitor $Y_c = \frac{1}{R_p} + j\omega C_p = 2.147 \cdot 10^{-6} + j6.195 \cdot 10^{-4}$
Impedance of capacitor $Z_C = \frac{1}{Y_c} = 5.595 - j1614.29 = 1614.30 \angle -89.80^o\ \Omega$

For the inductor:

L_s = 100.90 mH
R_s = 388.66 Ω
Impedance of Inductor $Z_L = R_s + j\omega L_s = 388.66 + j633.97 = 743.63 \angle 58.49^o\ \Omega$

For the resistor:

$Z_R = 993.2\angle 0^0$

Next, we measured the values for the resistor using the Elabo multimeter. The results are the following:

C = 98.59nF, L = 100.90 mH and R = 9932 Ω

Then, we assembled the circuit in the breadboard. A picture of the lab setup is provided below:

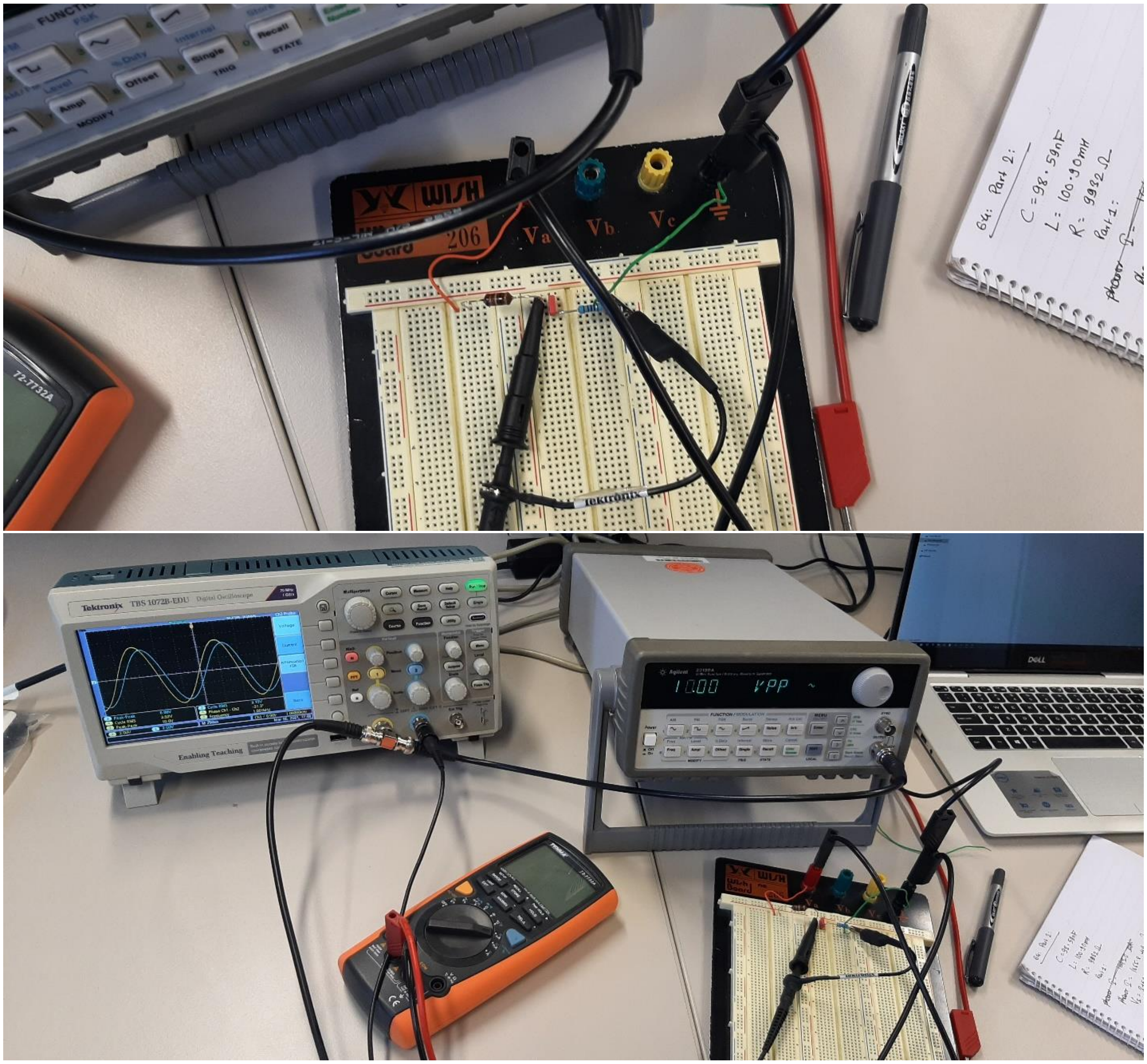


Fig 7: Assembly of circuit board

We set Vs = 5V∠0°, and recorded the phasor current from the TENMA multimeter (switched to AC current) in the μA range. We also measured the phasor voltages $\underline{V}_S$, $\underline{V}_R$ and $\underline{V}_{RC}$ using the Elabo multimeter. To get the complete phasors $\underline{V}_R$ and $\underline{V}_{RC}$, we measured the phase with the oscilloscope.

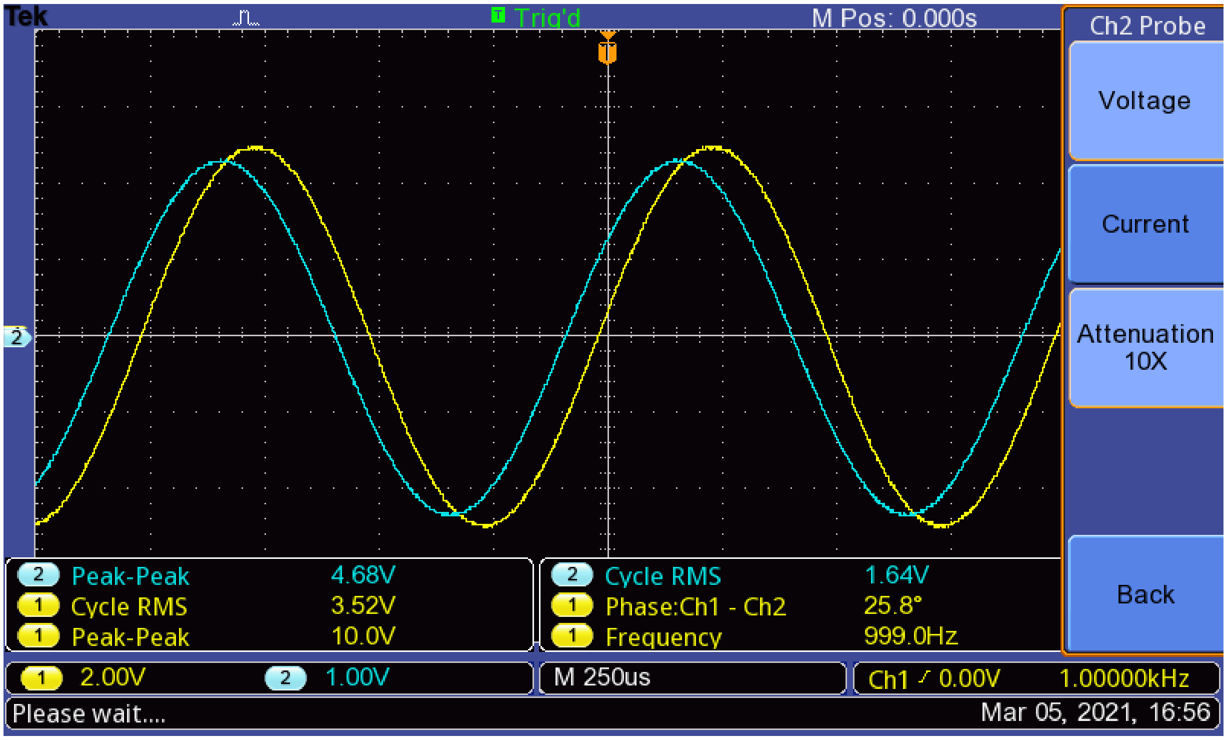


Fig 7: Oscilloscope reading for $\underline{V}_R$

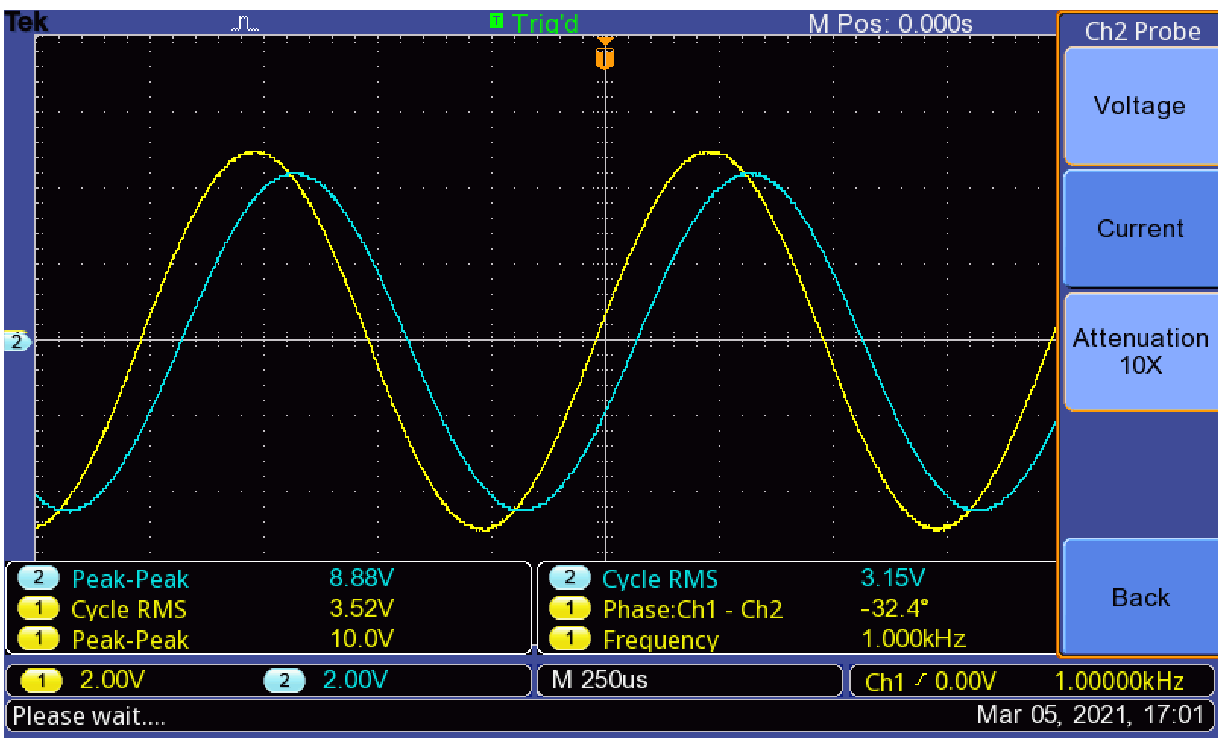


Fig 9: Oscilloscope reading for $\underline{V}_{RC}$

The results have been tabulated below:

Values	Elabo	Oscilloscope
$\boldsymbol{I}$	$1655.8\ \mu A$	$(1655.8\angle 25.8°)\mu A$
$\boldsymbol{V_s}$	$3.535V$	$(3.535\angle 0^o)\ V$
$\boldsymbol{V_R}$	$1.6392V$	$(1.64\angle 25.8°)V$
$\boldsymbol{V_{RC}}$	$3.177V$	$(3.15\angle -32.4°)V$

Table 3: Values measured with ELABO and TEKTRONIX.

3 Evaluation:

3.1 Part 1: Measure AC-Signal Properties

3.1.1 Calculating Theoretical Values of $\overline{v}$ and V_{RMS}

We know that the generator implements the following signal for the sine function:

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

Using the information, we have for the first set of settings, the signal generated by the Sine function, we can calculate the theoretical $\bar{v}$ and V as follows:

For offset = 0V,

$$V(t) = \sin(2000\pi t)\,V$$

$$\bar{v} = \frac{1}{T}\int_0^T \sin(2000\pi t)\,dt$$

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

$$\bar{v} = 1000\left[-\frac{\cos(2000\pi t)}{2000\pi}\right]_0^{\frac{1}{1000}}$$

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

$$V(t) = \sin(2000\pi t)\,V$$

We calculate the theoretical value for V_{RMS} as follows:

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

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

$$V_{RMS} = \sqrt{1000\int_0^{\frac{1}{1000}} \frac{1}{2}[1 - \cos(4000\pi t)]\,dt}$$

$$V_{RMS} = \sqrt{500\left[t - \frac{\sin(4000\pi t)}{4000}\right]_0^{\frac{1}{1000}}}$$

$$V_{RMS} = \sqrt{500 \cdot 0.001} = 0.707\,V$$

For offset = 1V,

$$\bar{v} = \frac{1}{T}\int_0^T (\sin(2000\pi t) + 1)\, dt$$

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

$$\bar{v} = 1000\left[-\frac{\cos(2000\pi t)}{2000\pi} + t\right]_0^{\frac{1}{1000}}$$

$$\bar{v} = 1.00V$$

$$V(t) = (\sin(2000\pi t) + 1)\, V$$

Again, we obtain V_{RMS} as follows:

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

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

$$V_{RMS} = \sqrt{1000\int_0^{\frac{1}{1000}} [\frac{1}{2}\{1 - \cos(4000\pi t)\} + 2\sin(2000\pi t) + 1]\ dt}$$

$$V_{RMS} = \sqrt{1000\left[0.5t - \sin\frac{(4000\pi t)}{8000\pi} - \cos\frac{(2000\pi t)}{1000\pi} + t\right]_0^{\frac{1}{1000}}}$$

$$V_{RMS} = \sqrt{1000 \cdot 0.0015}$$

$$V_{RMS} = 1.225\ V$$

The generator implements the following wave for the Exponential Fall (Exp_Fall) signal:

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

We can perform the same calculations for the results we get for the second set of settings, the exponential fall signal, as follows:

For offset = 0V, given the point (0.000081, 0.22) from the data we obtained from the oscilloscope (containing a screenshot of the oscilloscope reading and an excel sheet containing the points), we can calculate k as following:

$$0.22 = 2e^{k\times 0.000081} - 1$$

$$k = -6102.42\ s^{-1}$$

Now that we have a value for k, we can calculate $\bar{v}$ as the following:

$$\bar{v} = \frac{1}{T}\int_0^T (2e^{-6102.42t} - 1)dt$$

$$\bar{v} = 1000\int_0^{\frac{1}{1000}} (2e^{-6102.42t} - 1)dt$$

$$\bar{v} = 1000\left[\frac{2e^{-6102.42t}}{-6102.42} - t\right]_0^{\frac{1}{1000}}$$

$$\bar{v} = 672.97\ mV$$

$$V(t) = \ (2e^{-6102.42t} - 1)V$$

We can calculate V_{RMS} as follows:

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

$$V_{RMS} = \sqrt{1000\int_0^{\frac{1}{1000}} (2e^{-6102.42t} - 1)^2 dt}$$

$$V_{RMS} = \sqrt{1000\int_0^{\frac{1}{1000}} [4e^{2\cdot -6102.42t} - 2\cdot 2e^{-6102.42t} + 1]dt}$$

$$V_{RMS} = \sqrt{1000\left[\frac{4e^{-12204.84}t}{-12204.84} - \frac{4e^{-6102.42t}}{-6102.42} + t\right]_0^{1/1000}}$$

$$V_{RMS} = \sqrt{1000\cdot 0.0006737} = 0.821\ V$$

For offset = 1, we make the following adjustments:

We take the point (0.000261, 0.4) on the graph for offset = 1, and calculate k accordingly:

$$0.4 = 2e^{k\times 0.000261} - 1 + 1$$

$$k = -6166.429s^{-1}$$

$$\bar{v} = \frac{1}{T}\int_0^T (2e^{-6166.429t} - 1 + 1)dt$$

$$\bar{v} = 1000 \int_0^{\frac{1}{1000}} (2e^{-6166.429t})dt$$

$$\bar{v} = 1000 \left[\frac{2e^{-6166.429t}}{-6166.429}\right]_0^{\frac{1}{1000}}$$

$$\bar{v} = 323.656mV$$

$$V(t) = (2e^{-6166.429t})V$$

We calculate V_{RMS} as follows:

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

$$V_{RMS} = \sqrt{1000 \int_0^{\frac{1}{1000}} (2e^{-6102.42t})^2 dt}$$

$$V_{RMS} = \sqrt{1000 \int_0^{\frac{1}{1000}} [4e^{2\cdot -6102.42t}] dt}$$

$$V_{RMS} = \sqrt{1000 \left[\frac{4e^{-12204.84}t}{-12204.84}\right]_0^{1/1000}}$$

$$V_{RMS} = \sqrt{1000 \cdot 0.00032773}$$

$$V_{RMS} = 0.572\ V$$

3.1.2 Measuring and Calculating Values from Multimeter:

For Offset 0V in Sine Function:

Using Tenma, V_{AC} = 0.7042V and V_{DC} = 0V,

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

$$V_{RMS} = 0.7042V$$

This value is close to the V_{AC+DC} value.

For Offset 1V in Sine Function

V_{AC} = 0.7039V and V_{DC} = 0.9888V

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

$$V_{RMS} = 1.214\ V$$

The rms value slightly differs from the V_{AC+DC} value for offset 1V, but it’s still very close.

For Offset 0V in Exp_Fall Function

We measured V_{AC} = 0.4724V and V_{DC} = -0.6707V. We can therefore calculate V_{RMS} by using

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

$$V_{RMS} = \sqrt{(0.4724)^2 + (-0.6707)^2}$$

$$V_{RMS} = 0.82037V$$

Our calculated value for V_{RMS} is very close our measured value of V_{AC+DC}.

For Offset 1V in Exp_Fall Function

We measured V_{AC} = 0.3198V and V_{DC} = 0.64705V, we can use the same formula:

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

$$V_{RMS} = \sqrt{(0.3198)^2 + (0.5625)^2}$$

$$V_{RMS} = 0.64705V$$

In this case, our calculated value for the V_{RMS} is not close to our measured value for V_{AC+DC}.

	Tenma			Oscilloscope			Calculated	Theoretical
Wave at Generator	V_{DC}[V]	V_{AC}[V]	V_{AC+DC}[V]	V_{mean}[V]	V_{rms}[V]	V_{mean}[V]	V_{rms}[V]	V_{RMS}[V]
Sine, 2V_{PP}, 0V Offset	0V	0.7042V	0.7048V	0.0144V	0.721V	0V	$0.7042V$	$0.707\ V$
Sine, 2V_{PP}, 1V Offset	0.9888V	0.7039V	1.2092V	1.00V	1.24V	1.00V	$1.214\ V\ V$	$1.225\ V$
Exp_Fall, 2V_{pp}, 0V Offset	0.6707V	0.4724V	0.8232V	-0.696V	0.847V	0.673 V	0.820V	$0.821\ V$
Exp_Fall 2V_{pp}, 1V Offset	0.3198V	0.5625V	0.4685V	0.313V	0.574V	0.324V	0.647V	$0.572\ V$

Table 4: Values measured with ELABO and TEKTRONIX and calculated values.

When taking measurements during the experiment, we come across numerous errors. We don't account for contact error between components and the breadboard. Our measurements on the oscilloscope also have an error in the range 5-10%. This is a large source of error in our measurements. There is also a 2% error contributed by the signal generator, which means our signal is not exact, and also a 1-2% error on measurements made by the TENMA multimeter. We also have a propagated error when making calculations with measured values. All of these errors accumulate and provide us some measured values that are different from the actual values we are using. When we make calculations with erroneous values, we also find results that are different from the actual result due to error propagation. As a result, the value we measured with different tools and the values that we calculated end up being different.

For example, let us compare our measured V_{AC+DC} and measured V_{RMS}. All our measured values of V_{AC+DC} are more or less different from V_{RMS}. This is because our measurements of V_{AC}, V_{DC} and V_{AC+DC} have 1-2% error

There is the propagated error from V_{AC} and V_{DC} when calculating V_{RMS}. Again, we have an error of 1-2% on our TENMA multimeter measurements, which includes the V_{AC+DC}. These make the calculated value for V_{RMS} different from that of the measured V_{AC+DC}.

3.2 Part 2: Measure AC Circuit Properties:

To determine current and voltage values over every component using nominal input voltage and measured impedance values:

$$\hat{v} = 5 \angle 0^o V$$

$$V_{rms} = \frac{1}{\sqrt{2}} \cdot 5 \angle 0^o V = 3.54 \angle 0^o V$$

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

$Z = (993.2\angle 0^{\text{o}} + 743.63 \angle 58.49^o + 1614.30 \angle -89.80^o + 500\angle 0^o)\Omega$

$$Z = 2126.74\angle -27.44^o \ \Omega$$

Now, current $I = \frac{V_{rms}}{Z} = \frac{3.54 \angle 0^o V}{2126.74\angle -27.44^o \Omega} = 1.6645 \cdot 10^{-3} \angle 27.44^o A$

Voltage in inductor $V_L = I \cdot Z_L = (1.6645 \cdot 10^{-3} \angle 27.44^o) \cdot (743.63 \angle 58.49^o)$

$V_L = 1.238\angle 85.93^o V$

voltage on Capacitor $V_C = I \cdot Z_c = (1.6645 \cdot 10^{-3} \angle 27.44^o) \cdot (1614.30 \angle -89.80^o)$

$V_C = 2.687\angle -62.36^o V$

Voltage on Resistor $V_R = I \cdot Z_R = (1.6645 \cdot 10^{-3} \angle 27.44^o) \cdot (993.2\angle 0^{\text{o}})$

$V_R = 1.653\angle 27.44^o V$

Volage on Tenma $V_{Tenma} = I \cdot Z_{Tenma} = (1.6645 \cdot 10^{-3} \angle 27.44^o) \cdot (500\angle 0^{\text{o}})$

$V_{Tenma} = 0.8323\angle 27.44 \, V$

Determining the voltage across all components from measured voltage and current values:

Measured current on resistor $I = 1.6658 \cdot 10^{-3} \angle 25.8^o A$

Source voltage $\widehat{v_s} = 3.535 \angle 0^0 \ V$

Voltage on Resistor $v_R = 1.6392\angle 25.8^o \ V$

Voltage on Capacitor $v_C = V_{RC} - v_R = 3.177\angle -32.4^o - 1.6392\angle 25.8^o \ V$

$$\therefore v_C = 2.700 \angle -63.459^o V$$

Voltage on Tenma $v_{Tenma} = I \cdot Z_{Tenma} = 0.8329\angle 25.8^o V$

Voltage on Inductor $v_L = v_S - v_R - v_c - v_{Tenma} = 1.343\angle 85.609^o \ V$

	Measured Value	Calculated Value
I	$1.6658 \cdot 10^{-3}\angle 25.8^{o} A$	$1.6645 \cdot 10^{-3}\angle 27.44^{o} A$
v_R	$1.6392\angle 25.8^{o}\ V$	$1.653\angle 27.44^{o} V$
v_C	$2.700\angle -63.459^{o} V$	$2.687\angle -62.36^{o} V$
v_L	$1.343\angle 85.609^{o}\ V$	$1.238\angle 85.93^{o} V$
v_{Tenma}	$0.8329\angle 25.8^{o} V$	$0.8323\angle 27.44\ V$

Table 5: Measured and Calculated values.

From the measured current and voltage values:

Impedance of Resistor $Z_R = \frac{v_R}{I} = \frac{1.6392\angle 25.8^{o}\ V}{1.6658 \cdot 10^{-3}\angle 25.8^{o} A} = 984.03\ \Omega$

Impedance of Capacitor $Z_C = \frac{v_C}{I} = \frac{2.700\angle -63.459^{o} V}{1.6658 \cdot 10^{-3}\angle 25.8^{o} A} = 1620.84\angle -89.259^{o}\Omega = 20.962 - j1620.707\ \Omega$

$$Y_C = \frac{1}{Z_C} = (7.979 \cdot 10^{-6}) + j(6.169 \cdot 10^{-4}))$$

Comparing Y_C with $Y_C = \frac{1}{R_P} + j\omega C_P$

$R_P = 125.33\ K\Omega\ and\ C_P = 98.18\ nF$, with ω = 1000 Hz

Impedance of Inductor $Z_L = \frac{v_L}{I} = \frac{1.343\angle 85.609^{o}\ V}{1.6658 \cdot 10^{-3}\angle 25.8^{o} A} = 1240.84\angle -112.95^{o}\ \Omega = 405.435 + j696.859\Omega$

Comparing Z_L with $Z_L = R_S + j\omega L_s$

$R_s = 405.4\Omega\ and\ L_s = 110.9\ mH$

		Measured Element Value	Calculated Element Value
Capacitor	R_P	465.74 KΩ	125.33 KΩ
	C_P	98.59 nF	98.18 nF
Inductor	R_S	338.66 Ω	405.4 Ω
	L_S	100.90 mH	110.9 mH

Table 6: Capacitor and Inductor values.

The measured values of inductance and capacitance are close to the calculated ones, while the measured values for resistance (R_S and R_P) have a large difference from the calculated values. This can be attributed to the error caused while taking measurements with RLC meter and the TENMA multimeter, which is about 1-2% each. The oscilloscope also contributes 5-10% error when we use the "measure" function to take measurements. Other sources of error include the internal resistance of the wires, error due to contact with the breadboard, and use of connecting leads.

4 Conclusion:

In this lab, we learned how to set up an AC-circuit containing reactive components using a signal generator, and how to take measurements of the different components using TENMA multimeter and the oscilloscope. We learned how to use the AC and DC measurement components on the TENMA multimeter and how to use the "Measure" function in the oscilloscope to take readings. We also explored on how to analyze an AC-circuit with reactive components and saw how different components affect properties of the circuit like voltage and current. We studied how to generate different types of signals through the signal generator (sine and exponential fall), and which properties of the circuit change as a result.

Error analysis was also a very important part of the experiment, because we got to measure and calculate values for different components and compare them, which gave us an idea of how the error in measuring instruments affect our experimental data. We got a feel of best practices when taking measurements and what to avoid, and the differences we can expect in measured and calculated values of different components when they are measured by different tools.

5 References:

- Electrical Engineering-II Lab Manual (Uwe Pagel)
- http://www.faculty.jacobs-university.de/upagel/
- https://physics.stackexchange.com