Constructor University Bremen

Natural Science Laboratory
Electrical Engineering Module I

Fall Semester 2024

Lab Experiment 2 – AC Properties and Measurements

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Place of execution	: Teaching Lab 53
Date of execution	: March. 7, 2024

I Introduction

This experiment focuses on the essential characteristics of alternating current (AC) and the response of an RLC circuit under different conditions. It is divided into two key sections:

- **Analysis of AC Signals** – This part involves studying waveform properties such as peak-to-peak voltage, average voltage, and root mean square (RMS) values using measurement tools like an oscilloscope and a multimeter.
- **Investigation of AC Circuits** – In this section, an RLC circuit is assembled to observe and measure parameters like voltage, current, impedance, and phase differences, providing insight into its electrical behavior.

A clear understanding of these concepts is fundamental for developing and improving AC circuits, which are widely applied in areas such as electrical power systems, communication networks, and signal processing. Additionally, the experiment demonstrates the impact of different circuit components on signal characteristics, an important aspect of electrical and computer engineering.

When analyzing signals, we may encounter various responses such as sine waves, complex waves, square waves, triangular waves, etc. This illustration visually represents these waveforms.

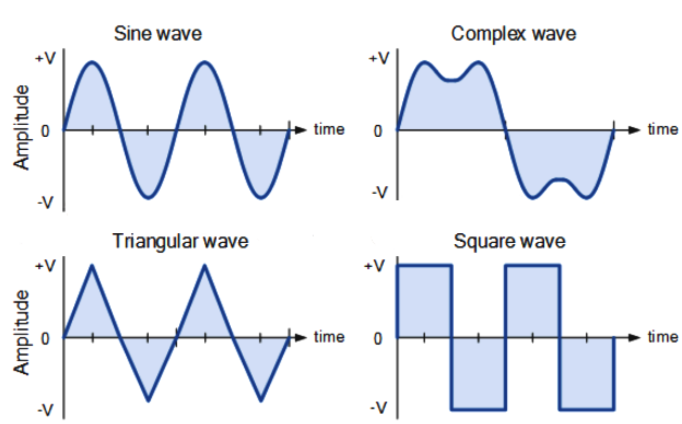


Figure 1. Diagrams of AC waveforms

Alternating current (AC) signals change periodically over time and can be expressed using sinusoidal equations:

$$V(t) = V_{max}\cos(\omega t + \theta)$$

$$I(t) = I_{max}\cos(\omega t + \theta)$$

Where:

- V_{max} and I_{max} represent the maximum voltage and current amplitudes.
- ω is the angular frequency defined as:

$$\omega = 2\pi f = \frac{2\pi}{T}$$

- θ is the phase angle, indicating the signal shift in time.

Investigated parameters:

- **Root Mean Square (RMS) Values** – These values indicate the effective voltage and current of an AC signal, allowing for a direct comparison with DC power dissipation. RMS values are particularly useful in power calculations, as they represent the equivalent heating effect of the AC waveform.
- **Cycle Mean Voltage** – This parameter represents the average voltage over one full cycle. It is especially important in circuits where DC components are present, as it helps in analyzing signal offsets and determining whether a waveform contains a net DC shift.
- **Peak-to-Peak Voltage (Vpp)** – Defined as the total voltage difference between the highest and lowest points of a waveform, this measurement is crucial for understanding signal strength, amplitude variations, and noise levels in AC circuits.
- **Duty Cycle** – This expresses the fraction of time a signal remains active within a single period.

To analyze key parameters of the AC circuit, we utilized the oscilloscope available in our lab and recorded our observations.

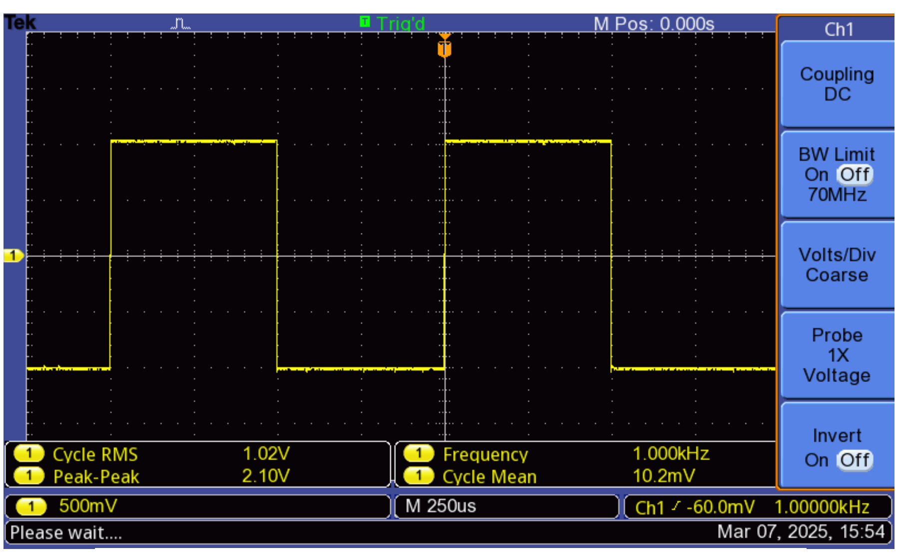


Figure 2. Hard copy of the Oscilloscope to record values

Impedance and Phase Relationship

Impedance (Z) represents the total opposition to current flow in an AC circuit, combining both resistance and reactance. For individual components, the impedance is defined as:

- $Resistor(R): Z_R = R$
- $Capacitor(C): Z_C = \frac{1}{j\omega C}$
- $Inductor(L): Z_L = j\omega L$

Here, j is the imaginary unit, and ω is the angular frequency.

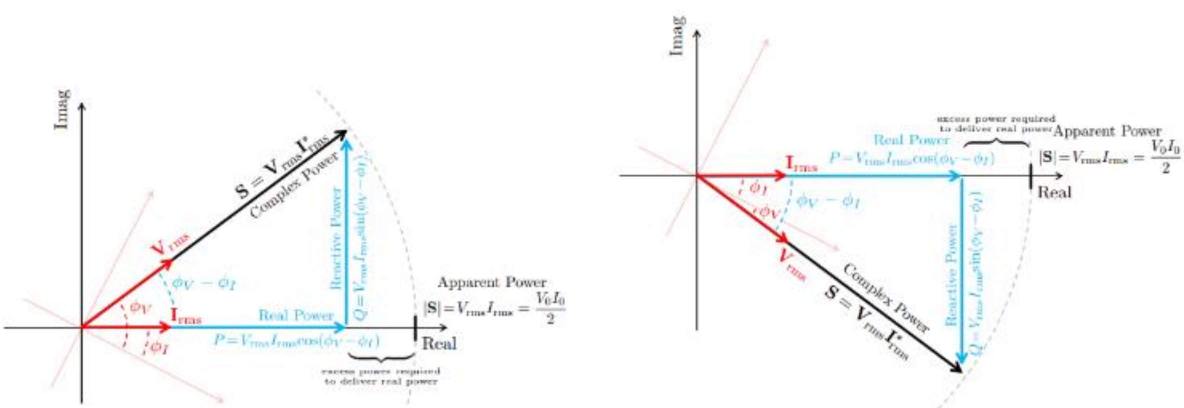
In an RLC series circuit, the total impedance is given by:

$$Z_{total} = R + j(\omega L - \frac{1}{j\omega})$$

The phase relationship between voltage and current plays a critical role in AC circuits. This interaction varies with the type of circuit:

- **Inductive Circuits** – In these circuits, the current lags the voltage by 90°.
- **Capacitive Circuits** – Here, the current leads the voltage by 90°.

Understanding these phase shifts is crucial for applications like designing AC filters, resonance circuits, and ensuring impedance matching in radio frequency (RF) systems.



(a) Lagging

(b) Leading

Figure 3. Diagrams for Inductive and Capacitive Circuits

2. Experimental Part 1 – Measure AC signal Properties – Square Wave

Workbench No.8

Used tools and Instruments:
- Signal Generator
- TENMA Multimeter
- BNC Cable, Banana Connector, T Connector
- Oscilloscope
- 50 Ohm Resistor

Function Generator Settings:
- Waveform: Square
- Frequency: 1 kHz
- Peak-to-Peak Voltage (Vpp): 2.04V
- Offset: 0V

Description of the Measurements

For our measurements, we first used the oscilloscope's measurement function to record the peak-to-peak voltage (Vpp), the mean voltage (Vmean), and the root mean square (RMS) voltage (V_RMS). We applied both the RMS Cycle and Mean Cycle functions to obtain these values and printed hard copies for documentation.

Next, we used the multimeter to measure the voltage in both AC and DC ranges, ensuring that only the 'AC' reading appeared on the display for the AC measurement.

The TENMA multimeter also allowed us to directly measure the combined AC+DC RMS value. We switched the multimeter to the VAC setting and pressed the 'AC+DC' button. The display confirmed that the 'AC+DC' mode was active, and we recorded the resulting values.

Then, we adjusted the DC offset of the waveform to 1V, resulting in the signal oscillating between 0V and 2V. We repeated the measurement process with both the oscilloscope and multimeter, just as described above, to ensure accuracy and consistency.

According to the data the following table were made:

Measured by Oscilloscope			Measured by Multimeter		
Vpp(V)	V_mean (mV)	V_rms (V)	V_ac (V)	V_dc (V)	V_ac+dc(V)
2.1	10.2	1.02	1.0035	0	1.0039

Table 1. Measured Voltage parameters 0V Offset – Square Wave

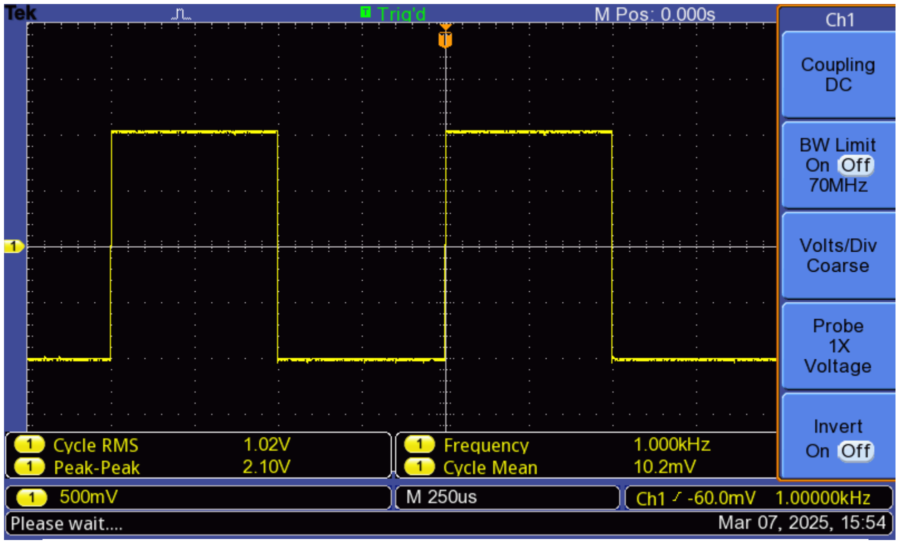


Figure 4. Hard copy of the Oscilloscope 0V Offset – Square Wave

Changing of the Offset by 1 Volt.

Measured by Oscilloscope			Measured by Multimeter		
Vpp (V)	V_mean (V)	V_rms (V)	V_ac (V)	V_dc (V)	V_ac+dc(V)
2.06	1.01	1.43	1.0034	0.99	1.4069

Table 2. Measured Voltage parameters 1V offset – Square Wave

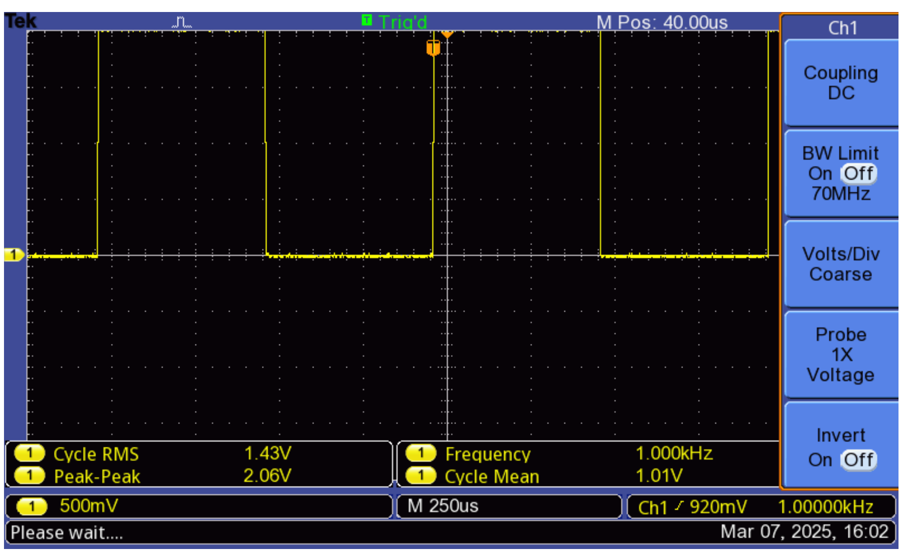


Figure 5. Hard copy of the Oscilloscope 1V Offset – Square Wave

3. Experimental Part 1 – Measure AC Circuit Properties – Exponential

Workbench No.8

Used tools and Instruments:

- Signal Generator
- TENMA Multimeter
- BNC Cable, Banana Connector, T Connector
- Oscilloscope
- 50 Ohm Resistor

Function Generator Settings:

- Waveform: Exponential Fall
- Frequency: 1 kHz
- Peak-to-Peak Voltage (Vpp): 2.04V
- Offset: 0V
- Amplitude $\pm 1\ V$ wave

According to the data the following table were made:

Measured by Oscilloscope			Measured by multimeter		
Vpp (V)	V_mean (mV)	V_rms (mV)	V_ac (V)	V_dc (V)	V_ac+dc(V)
2.06	-674	827	0.4719	-0.6726	0.8234

Table 3. Measured Voltage parameters 0V offset – Exp Wave

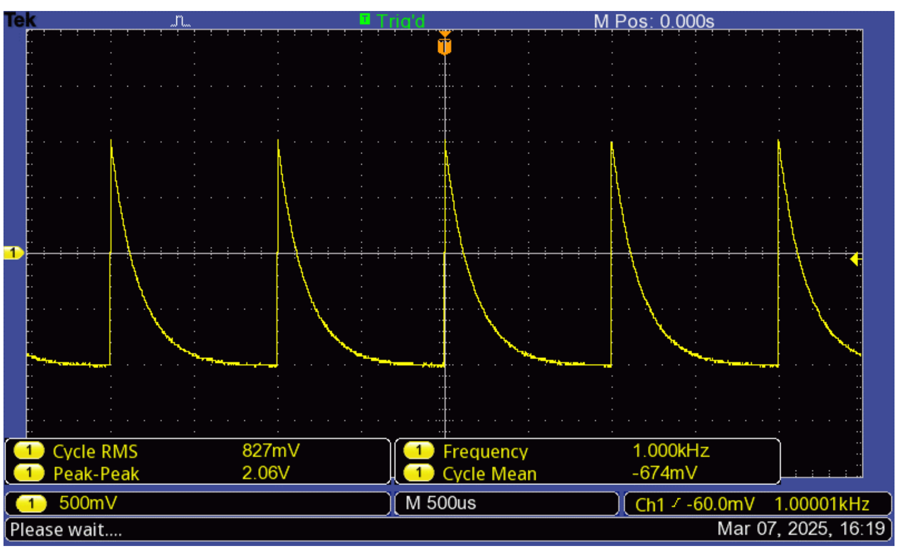


Figure 6. Hard copy of the Oscilloscope 0V Offset – Exp Wave

Changing of the Offset by 1 Volt.

Measured by Oscilloscope			Measured by Multimeter		
Vpp (V)	V_mean (mV)	V_rms (mV)	V_ac (V)	V_dc (V)	V_ac+dc(V)
2.04	338	587	0.4694	0.3227	0.5669

Table 4. Measured Voltage parameters 1V offset – Exp Wave

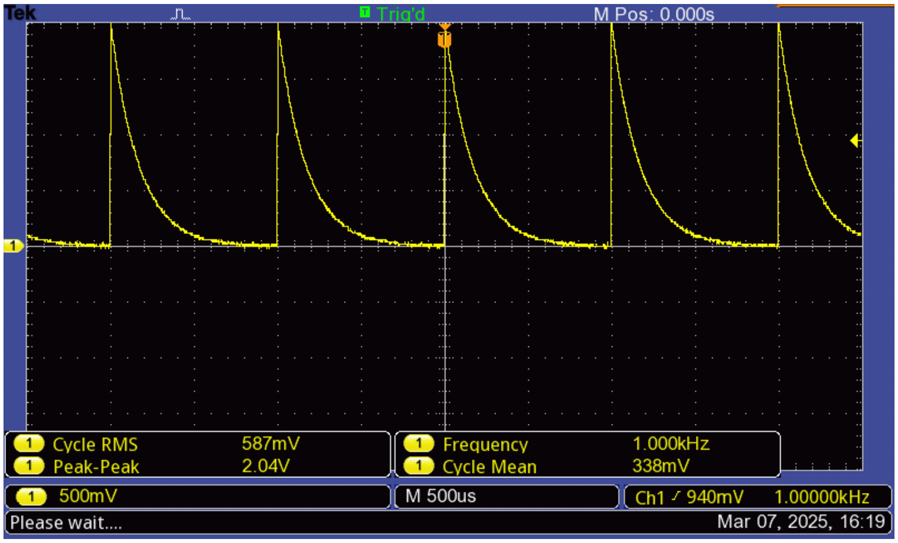


Figure 7. Hard copy of the Oscilloscope 1V Offset – Exp Wave

4. Experimental Part 1 – Measure AC Circuit Properties – RLC Circuit

Workbench No.8

Used tools and Instruments:
- Signal Generator
- TENMA Multimeter
- BNC Cable, Banana Connector, T Connector
- Oscilloscope
- 1000 Ohm Resistor
- 100 mH Inductor
- 15 nF Capacitor

Function Generator Settings:
- Waveform: Sinusoidal

- Frequency: 1 kHz
- Peak-to-Peak Voltage (Vpp): 10V
- Offset: 0V
- Amplitude 5 V

Test Circuit

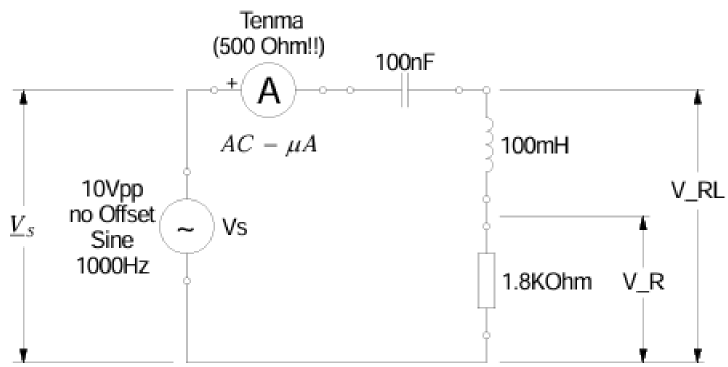


Figure 6. Experimental Circuit for experimental part 2

Description of the Measurements

During the experiment, we first located the components of the circuit in the kit as shown in the diagram. We then measured the impedance and element values of the inductor and capacitor at a frequency of 1 kHz using the RLC meter. For the inductor, we used the series substitute circuit, and for the capacitor, we used the parallel substitute circuit. To determine the exact resistance values, we utilized the ELABO multimeter.

For all measurements, the reference signal was $\widehat{V_s} = 5V\angle 0^{\circ}$.

We recorded the phaser current using the TENMA multimeter, making sure to switch to the AC mode and using the microamp range.

We measured the phaser voltages V_S, V_R and V_{RL} with the ELABO multimeter.

To obtain the complete phasors for V_R, V_{RL}, and the current, we measured the phases using the oscilloscope. We connected channel 1 to V_S as the reference signal (phase 0°) and the second signal to channel 2. Using the oscilloscope's measure function (Phase CH1-CH2), we calculated the phase difference.

According to the data the following table were made:

Parameter	Voltage(V)/Current(A)	Phase	Phasor Form
I_s	$1182.7*10^{-6}$	20.8	$1182.7*10^{-6}\angle 20.8$
V_R	2.187	20.8	$2.187\angle 20.8$
V_RL	2.8	37.1	$2.8\angle 37.1$
V_S	3.785	0	$3.785\angle 0$

Table 5. Measured Voltage parameters of AC signal - 1V offset

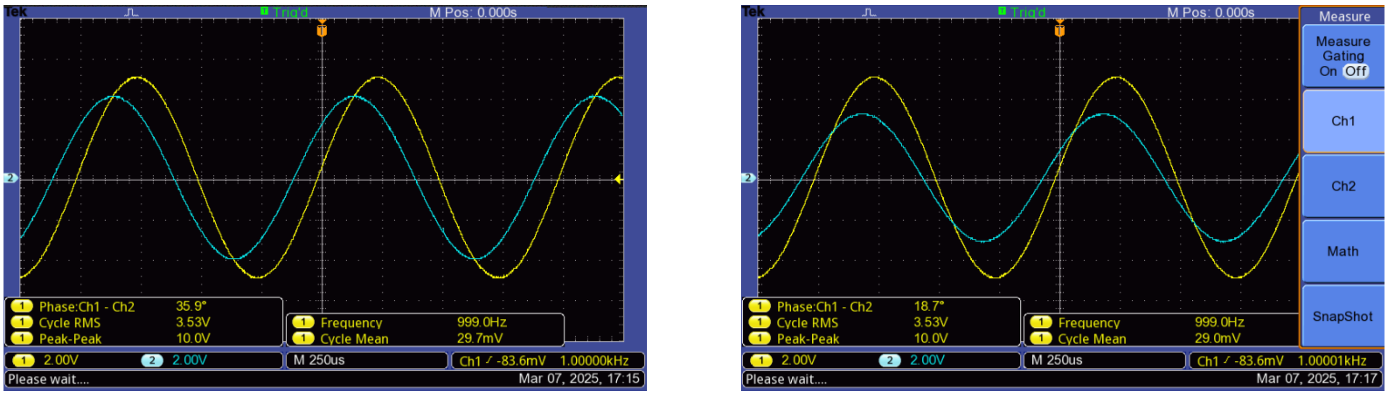


Figure 7-8. Hard copy of the Oscilloscope to observe on the phase difference and the voltage a) across resistor and inductor and b) across the resistor

Impedances and Element real values were measured by RLC meter

Cp(F)	Rp(ohm)	Ls(H)	Rs(ohm)
$99.75*10^{-9}$	456300	$102.5*10^{-3}$	405.65

Table 6. Measured values of all components

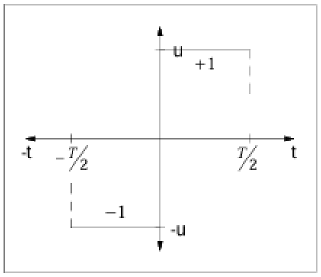
Element	Magnitude(ohm)	Phase	Impedance
Resistor	1792	0	$1792\angle 0$
Capacitor	1619.5	-89.98	$1619.5\angle -89.98$
Inductor	743.25	59.73	$743.25\angle 59.73$

Table 7. Impedances of all elements

5 Evaluation

Part 1 – Measure AC Signal Properties

To calculate the mean voltage and RMS voltage for Square Wave we know that the following formula is implemented in the Signal Generator:



$$V = f(t) = \begin{cases} -\hat{u} + u_{off} & : \quad -\frac{T}{2} \leq t \leq 0 \\ \hat{u} + u_{off} & : \quad 0 \leq t \leq \frac{T}{2} \end{cases}$$

For a square wave signal this formula can be used to determine voltage parameters when the offset is equal to 0.
Assuming that $\hat{u} = 1$

$$V_{mean} = \frac{1}{T}\int_0^T v(t)dt \qquad and \qquad V_{RMS} = \sqrt{\frac{1}{T}\int_0^T (v(t))^2 dt}$$

To calculate mean and RMS voltage given offset = 0V

$$V(t) = \begin{cases} -1, & -T/2 \leq t < 0 \\ 1, & 0 \leq t < T/2 \end{cases}$$

$$\boldsymbol{V_{mean}} = \frac{1}{T}\left[\int_{-T/2}^{0}(-1)dt + \int_0^{T/2}(1)dt\right] = \frac{1}{T}\left(\frac{T}{2} - \frac{T}{2}\right) = 0\ V$$

$$\boldsymbol{V_{RMS}} = \sqrt{\frac{1}{T}\left[\int_{-\frac{T}{2}}^{\frac{T}{2}} V^2(t)dt\right]} = \sqrt{\frac{1}{T}\int_{-\frac{T}{2}}^{0} u^2 - 2u_{off} + u_{off}^2 dt + \int_0^{\frac{T}{2}} u^2 + 2u_{off} + u_{off}^2\, dt} =$$

$$= \sqrt{\frac{1}{T}\left[u^2 * \frac{T}{2} - 2u_{off}u * \frac{T}{2} + u_{off}^2 * \frac{T}{2} + \frac{u^2T}{2} + 2u_{off} * \frac{T}{2} + u_{off}^2 * \frac{T}{2}\right]} = \sqrt{1^2 + 0^2} = \sqrt{1} = 1\text{ V}$$

To calculate mean and RMS voltage given offset = 1V

$$V(t) = \begin{cases} -1 + 1, & -T/2 \leq t < 0 \\ 1 + 1, & 0 \leq t < T/2 \end{cases}$$

$$\boldsymbol{V_{mean}} = \frac{1}{T}\left[\int_{-T/2}^{0}(0)dt + \int_0^{T/2}(2)dt\right] = \frac{1}{T}(0 + T) = 1\ V$$

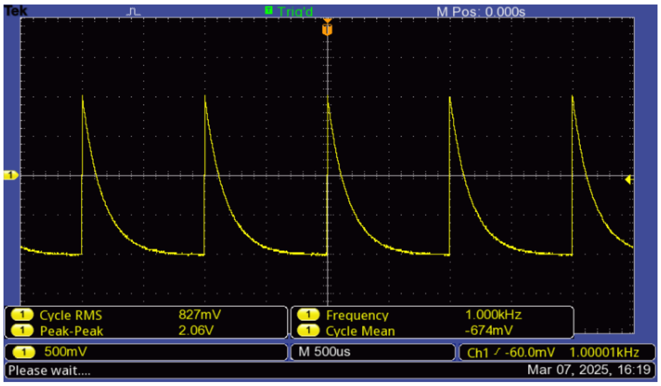
$$V_{RMS} = \sqrt{\frac{1}{T}\left[\int_{-T/2}^{0} 0^2 dt + \int_{0}^{T/2} 2^2\right]} = \sqrt{\frac{1}{T}\left(0 + \frac{T}{2} * 4\right)} = \sqrt{2} \approx 1.41\ V$$

To calculate the mean voltage and RMS voltage for Exponential Fall Wave we know that the following formula is implemented in the Signal Generator:

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

Where k is a constant.

To determine constant k, we can observe the hardcopy of the Oscilloscope



From this Hardcopy we can see that the mean Voltage is 1.03V. We can take a point at t = $50\mu s$ when $f(t) = 0$.

$$k = \frac{1}{T} ln\left(\frac{1}{2} + \frac{f(t) - V_{off}}{2\hat{v}}\right) = -6052s^{-1}$$

Now, we have the calculated value for k, so we can rewrite the formula as:

$$f(t) = 2\left(2^{1-tln2*10^4+1}\right) + V_{off}$$

To calculate mean Voltage given offset = 0V

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

After substitute values

$$V_{mean} = 1 * \left(\frac{2(1 - 0.00235)}{6.052} - 1\right) = \left(\frac{2 * 0.99765}{6.052} - 1\right) = 0.33 - 1 = -0.670\ V$$

To calculate RMS Voltage given offset = 1V

$$\boldsymbol{V_{mean}} = 1 * \left(\frac{2(1-0.00235)}{6.052} - 1\right) + 1 = \left(\frac{2 * 0.99765}{6.052} - 1\right) + 1 = 0.33 - 1 + 1 = 0.330\ V$$

When $V_{off} = 1\ V, \hat{v} = 1\ V\ and\ T = 10^{-3}, \bar{V} = 0.330\ V$
When $V_{off} = 0\ V\ , \bar{V} = -0.670\ V$

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

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

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

$$= \sqrt{\frac{1}{T}\left[\hat{v}^2\int_0^T (4e^{2kt} - 4e^{kt} + 1)dt + v_{\text{off}}^2 \cdot T + 2\hat{v}v_{\text{off}}\int_0^T (2e^{kt} - 1)dt\right]}$$

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

By substitute the values we get the final RMS voltages:

When $V_{off} = 1\ V, \quad V_{RMS} = 0.575\ V$

When $V_{off} = 0\ V, \quad V_{RMS} = 0.819\ V$

Upon reviewing the results, we found that the measurements obtained from both the oscilloscope and multimeter were in close agreement with the theoretical predictions. However, we did observe some small discrepancies, which could be attributed to various factors:

- **Instrument Limitations**: Both the oscilloscope and the TENMA multimeter have inherent accuracy limits, typically with a tolerance of about 1-3%. This can introduce slight variations in the recorded values.
- **Signal Behavior**: Exponential signals, especially during decay, can be tricky to measure accurately. The quick transitions in the waveform sometimes led to minor miscalculations, as both instruments struggled to capture the instantaneous values during these rapid changes.

- **Setup Variations**: Small errors in the adjustment of the offset voltage from the function generator, along with the resistances and inductances in the connecting cables, could have contributed to slight discrepancies in the results.
- **External Influences**: Environmental factors, such as electrical noise in the lab or imperfections in the wiring and connections, may have had a minor impact on the accuracy of the measurements.

Despite these potential sources of error, the measured values generally remained within an acceptable margin of error (less than 3%), indicating that the setup and instruments used were reliable and accurate overall.

Final Results

Square Wave – 0V Offset

Parameter	Theoretical	Oscilloscope	Multimeter
V_mean	0 V	0.0102 V	1.0035 V
V_rms	1.00 V	1.02 V	1.0035 V
V_DC	0 V	-	0 V
V_AC+DC	1.00 V	-	1.0039 V

Table 8. Measured Voltage parameters of AC signal - 0V offset

To measure RMS value for Multimeter we used the following formula:

$$\boldsymbol{V_{RMS}} = \sqrt{{V_{AC}}^2 + {V_{DC}}^2} = \sqrt{1.0035^2 + 0^2} \approx 1.0035\ V$$

To calculate the %error compared to theoretical

$$\%\boldsymbol{Error} = \frac{1.0035 - 1}{1} * 100 = 0.35\%$$

Square Wave – 1V Offset

Parameter	Theoretical	Oscilloscope	Multimeter
V_mean	1 V	0.01 V	0.99 V
V_rms	1.41 V	1.43 V	V_AC: 1.0034 V V_DC: 0.99 V
V_AC+DC	1.41 V	-	1.4069 V

Table 9. Measured Voltage parameters of AC signal - 1V offset

To measure RMS value for Multimeter we used the following formula:

$$\boldsymbol{V_{RMS}} = \sqrt{{V_{AC}}^2 + {V_{DC}}^2} = \sqrt{1.0034^2 + 0.99^2} \approx 1.409\ V$$

Exponential Wave – 0V Offset

Parameter	Theoretical	Oscilloscope	Multimeter
V_mean	-0.670 V	-674 mV	V_DC: -0.6726 V
V_rms	0.575 V	827 mV	V_AC: 0.4719 V V_DC: -0.6726 V

Table 10. Measured Voltage parameters of AC signal - 0V offset

RMS by Multimeter:

$$\boldsymbol{V_{RMS}} = \sqrt{{V_{AC}}^2 + {V_{DC}}^2} = \sqrt{0.4719^2 + 0.6726^2} \approx 0.82\ V$$

$$\%\boldsymbol{Error} = \frac{0.82 - 0.827}{0.827} * 100 = -0.85\%$$

Exponential Wave – 1V Offset

Parameter	Theoretical	Oscilloscope	Multimeter
V_mean	0.330V (from earlier: -0.670+1)	388 mV	V_DC: 0.3227 V
V_rms	0.819 V	587 mV	V_AC: 0.4694 V V_DC: 0.3227 V

Table 11. Measured Voltage parameters of AC signal - 1V offset

RMS by Multimeter:

$$\boldsymbol{V_{RMS}} = \sqrt{{V_{AC}}^2 + {V_{DC}}^2} = \sqrt{0.4694^2 + 0.3227^2} \approx 0.566\, V$$

$$\%\boldsymbol{Error} = \frac{0.566 - 0.587}{0.587} * 100 = -3.57\%$$

Part 2 – RLC Circuit

$$Z_T = Z_C + Z_R + Z_L + Z_{TENMA}$$

Capacitor is in parallel with R_P resistor, so the total impedance can be calculated as:

$$Z_C = \left(\frac{1}{\frac{1}{R_P} + j\omega C}\right)$$

The following values were measured:

$$Z_{TENMA} = 500\ \Omega; \quad Z_R = 1792\angle 0; \quad Z_C = 1619.5\angle -89.98; \quad Z_L = 743.25\angle 59.73$$

As we know:

$$i(t) = \frac{v(t)}{Z_T} = \frac{5\angle 0}{2854.28\angle - 20.12} = 1.7517 * 10^{-3}\angle 20.12$$

Now, we can calculate the voltages across all elements of the circuit:

$$\widehat{V_R} = i(t) * R = (1.7517 * 10^{-3}\angle 20.12) * 1792 = 3.14\angle 20.12\ \text{V}$$

$$\widehat{V_T} = (1.7517 * 10^{-3}\angle 20.12) * 500\angle 0 = 0.88\angle 20.12\ \text{V}$$

$$\widehat{V_L} = (1.7517 * 10^{-3}\angle 20.12) * 743.25\angle 58.83 = 1.30\angle 78.95\ \text{V}$$

$$\widehat{V_C} = (1.7517 * 10^{-3}\angle 20.12) * 1619.5\angle - 89.98 = 2.83\angle - 69.86\ \text{V}$$

From here we can determine $V_L, V_T\ and\ V_C$

$$V_L = V_{RL} - V_R = 2.187\angle 20.8 - 2.80\angle 37.1 = 0.93\angle 78.31$$

$$V_T = \frac{V_R}{Z_R} * Z_T = 0.61\angle 20.8$$

$$V_C = V_S - V_L - V_T - V_R = 2.14\angle - 62.72$$

Finally, we found theoretical value of I(t) and it is $1.7517*10^{-3}\angle 20.12$
Theoretical RMS value is:

$$i_{RMS} = \frac{i(t)}{\sqrt{2}} = 1.23\angle 20.12$$

Quantity	Measured	Calculated
I_S	$1182.7 * 10^{-6}\angle 20.8$	$1.237 * 10^{-6}\angle 20.12$
V_L	$0.93\angle 78.31$	$0.9317\angle 78.31$
V_R	$2.187\angle 20.8$	$2.220\angle 20.12$
V_C	$2.14\angle - 62.72$	$2.83\angle - 69.86$
V_T	$0.61\angle 20.8$	$0.88\angle 20.12$

Table 12. Comparison between measured and calculated values

$$Z_R = \frac{\widehat{v_R}}{\hat{\imath}} = \frac{2.187\angle 20.8}{1182.7 * 10^{-6}\angle 20.8} = 1849.16\angle 0$$

$$Z_L = \frac{\widehat{v_L}}{\hat{\imath}} = \frac{0.93\angle 78.31}{1182.7 * 10^{-6}\angle 20.8} = 786.3\angle 57.51$$

$$img(Z_L) = \omega L \quad and \quad Re(Z_L) = RL = 452\ \Omega$$

$$L = \frac{img(Z_L)}{\omega} = \frac{663.26}{2\pi * 1000} = 0.1056\ H$$

$$Z_C = \frac{\widehat{v_C}}{\hat{\imath}} = \frac{2.14\angle - 62.72}{1182.7 * 10^{-6}\angle 20.8} = 1809.42\angle - 83.52 = 204.20 - 1797.86\mathrm{j}$$

$$img(Z_C) = \frac{1}{\omega C} \quad and \quad Re(Z_C) = RC$$

$$C = -\frac{1}{img(Z_C) * 2\pi * 1000} = 88.52 * 10^{-9}\ F$$

6 Analysis and Discussion

The experimental results closely align with theoretical predictions, confirming the accuracy of the impedance and phase shift calculations. Key observations include:

- **Impedance Verification:** The measured voltage drops across the circuit components are consistent with theoretical impedance values.
- **Phase Shift Analysis:** The observed phase shifts accurately reflect the expected behavior of inductive and capacitive elements.
- **Minor Discrepancies:** Small deviations can be attributed to measurement limitations, wiring resistance, and external signal noise.

Sources of Error and Mitigation

- **Instrument Calibration:** Regular calibration of the oscilloscope and multimeter ensures measurement accuracy.
- **Component Tolerances:** Using high-precision resistors and capacitors reduces variations in expected values.

7 Conclusion

This experiment successfully explored the essential properties and behaviors of AC signals and RLC circuits. In the AC Signal Analysis section, square wave and exponentially decaying waveforms were examined to compare theoretical predictions with actual measurements. The results showed a strong correlation between theory and measurements, with only minor discrepancies attributed to instrument limitations, waveform complexity, and slight setup imperfections.

The AC RLC Circuit Analysis validated key impedance concepts, confirming the expected voltage drops, current behavior, and phase shifts across resistive, inductive, and capacitive components. The calculated values were in close agreement with the measurements, especially for the capacitor, though minor differences were observed for the inductor and resistor. These differences were likely due to component tolerances, measurement inaccuracies, and the inherent limitations of the laboratory equipment.

Overall, the experiment reaffirmed the accuracy of theoretical AC circuit analysis, highlighting the critical role of precise measurement techniques and high-quality instrumentation. Future experiments could improve accuracy by using more precise components, conducting more thorough calibration, and implementing better strategies to reduce external interference.

8 References

1. http://uwp-cu-lab.my-board.org/?i=1
2. Fundamental of Electric Circuits – Sadiku
3. https://en.wikipedia.org/wiki/RLC_circuit
4. https://www.montana.edu/rmaher/ee101/ecebot/fl07_notes/ee_101_lab03_ac_F07.pdf