design and construction of a SINGLE PHASE RLC (RESISTOR, INDUCTOR AND CAPACITOR) TRAINER

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MAY, 2025

PRESENTATION OUTLINE

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1.1 INTRODUCTION

- The RLC Trainer is an essential educational tool used in electrical and electronics engineering laboratories to study the behavior of Resistors (R), Inductors (L), and Capacitors (C) in various circuit configurations.
- This trainer allows students to perform hands-on experiments on measurement of power factor, series and parallel RLC circuits, and to analyze resonance conditions
- Main Components
- Adjustable R, L, C elements for circuit configuration.
- Function generator (for AC signal input).
- Measurement tools (multifunctional meter, oscilloscope).

2. PROBLEM STATEMENT

This study examines the persistent challenges students encounter when conducting RLC circuit experiments, where significant discrepancies exist between theoretical predictions and practical measurements of key parameters like resonance frequency ($f_0 = 1/(2\pi\sqrt{LC})$), quality factor (Q) (Nilsson & Riedel, 2019; Alexander & Sadiku, 2021). These experimental difficulties rise from three primary sources: (1) measurement inaccuracies in laboratory settings, (2) non-ideal characteristics of physical components, and (3) complexities in analyzing phase relationships between voltage and current waveforms (Dorf & Svoboda, 2014; Hambley, 2018). This trainer aims to systematically examine and quantifying measurement errors, analyzing sources of discrepancy, and developing improved RLC trainer for enhancing student understanding of RLC circuit.

3. AIM OF THE PROJECT

To design and construct an RLC trainer that demonstrates the principles and behaviors of RLC circuit

4. OBJECTIVES OF THE PROJECT

The objectives are:

- Study the behavior of resistors (R), inductors (L), and capacitors **(C)** in AC circuit
- Determine the resonant frequency in series RLC circuit
- Analyze bandwidth, quality factor (Q-factor), and selectivity of resonant circuits.
- To provide a tool for analyzing power factor, enabling students to see the effects of inductive and capacitive loads on AC circuits
- To integrate use of external tools, such as a function generator and an oscilloscope, for waveform analysis and frequency adjustments in AC signal input

5. SCOPE OF STUDY

This study focuses on the design and construction of an RLC circuit trainer for educational purposes, covering series and parallel configurations with variable resistors, inductors, and capacitors to demonstrate fundamental AC circuit principles, analyzing resonance frequency, damping effects, and phase relationships, while incorporating safety features such as fuse protection and insulated probes. However, the study is limited to low-power AC circuits (under 50V) and does not address high-power industrial applications. Additionally, while the trainer allows component interchangeability, it is constrained by fixed measurement ranges and does not include automated data logging capabilities.

6. LITERATURE REVIEW

- RLC trainers are widely used to bridge the gap between theory and practice (Nilsson & Riedel, 2019).
- They help students visualize abstract concepts like impedance, reactance, and phase shifts (Alexander & Sadiku, 2021).
- Studies show that hands-on experimentation improves retention of circuit analysis principles (Dorf & Svoboda, 2014).
- Experimental determination of resonant frequency (fr=12πLC*fr*=2π*LC*1) often deviates from theory due to component tolerances and parasitic effects (Hambley, 2018).
- Research emphasizes the need for calibration and precise measurements to minimize errors in Q-factor and bandwidth analysis (Mazda, 2009).

7. METHODOLOGY

Methodology and Construction Highlights of an RLC Trainer

1. Circuit Construction & Design

The RLC trainer is designed as a **modular, user-friendly platform** for hands-on experiments in circuit analysis. Key construction features include:

Component Selection:

- **Precision resistors** (1Ω–1MΩ, ±1% tolerance)
- **Air-core inductors** (1mH–100mH) to minimize core losses
- **Film capacitors** (1nF–100μF, low ESR) for stable frequency response
- **Variable components** (potentiometers, tunable inductors/capacitors) for flexibility

Board Layout:

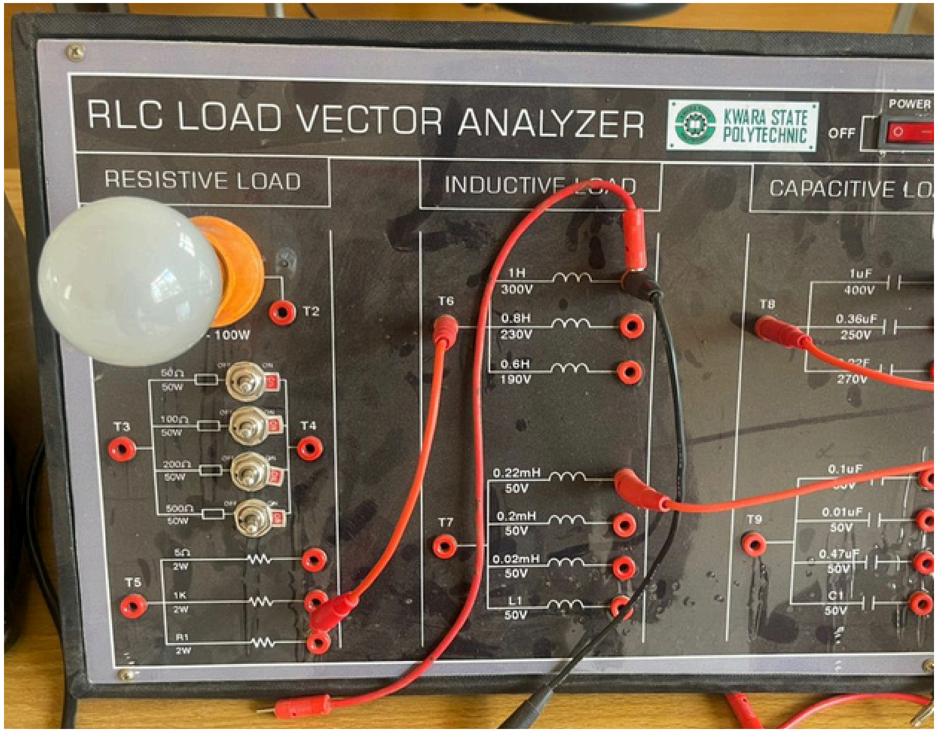
- **Solderless breadboard section** for custom circuits
- **Fixed RLC modules** for quick series/parallel configurations
- **Banana jacks** for easy instrument connections (oscilloscope, function generator)
- **Shielded wiring** to reduce electromagnetic interference

Safety Features:

- Fused power inputs
- Overcurrent protection
- Clear labeling of test points

The project work will involve the following stages:

- **Input power (AC):** The power supplied by the AC source is distributed differently across resistive and reactive components.
- **Energy MultiMeter**: An instrument or module used to measure the electrical energy consumed by the circuit over time.
- **Function Generator:** serving as the signal source that excites the RLC circuit for analysis. Its primary role is to provide controlled, adjustable waveforms(sine wave) to study the circuit's behavior under different input conditions.
- **RLC Load:** An RLC load refers to an electrical circuit or component that consists of a combination of:
- **Resistor (R)** – Provides opposition to current (dissipates power as heat).
- **Inductor (L)** – Stores energy in a magnetic field (opposes changes in current).
- **Capacitor (C)** – Stores energy in an electric field (opposes changes in voltage).
- **Oscilloscope:** providing real-time visualization and measurement of voltage signals across components


RLC LOAD VECTOR ANALYZER
KWARA STATE POLYTECHNIC
POWER
OFF
RESISTIVE LOAD
INDUCTIVE LOAD
T2
T3
T4
T5
T6
T7
T8
T9
1H
300V
0.8H
230V
0.6H
190V
0.22mH
50V
0.2mH
50V
0.02mH
50V
L1
50V
1uF
400V
0.36uF
250V
270V
0.1uF
0.01uF
50V
0.47uF
50V
C1
50V

MULTIFUNCTION
DIGITAL METER PANEL
(SINGLE PHASE/THREE PHASE AC 50Hz)
INPUTS
OUTPUTS
MULTIFUNCTION METER
POWER
KWARA STATE POLYTECHNIC
MODEL: MDMP - 024EE

Objective: To understand the concept of power factor and measure the power factor of different types of loads.

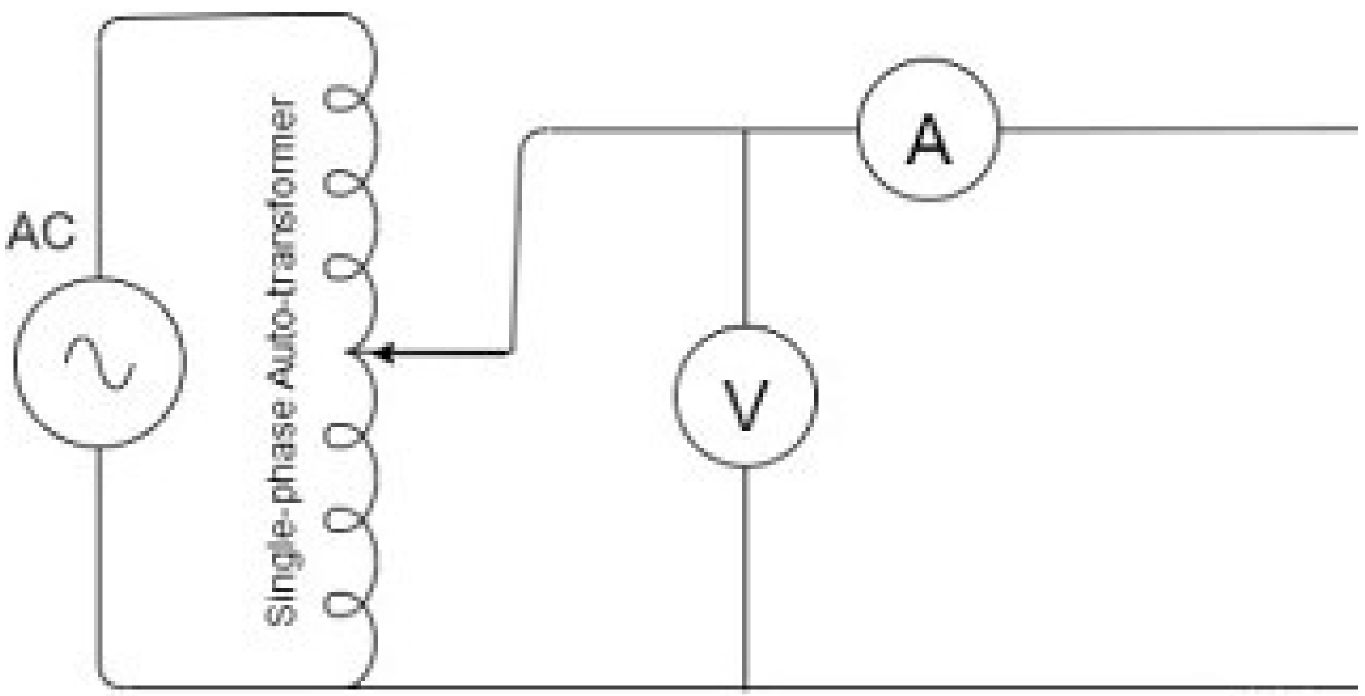


Figure 1: Circuit Diagram for Power Factor Measurement

OBSERVATION TABLE:

Table 1:Measurement of Power Factor

Load Type	Voltage (V)	Current (I) (A)	Apparent power (S) = (VxI) VA	Active Power (P) W	Power Factor (PF) Cos θ
Resistive (R)(100w bulb)	195	0.34	66.3	66	**0.995**
Inductive (L) (0.8H)	198	0.089	17.6	6	**0.34**
Capacitive (C) (1uF)	197	0.124	24.4	0.000	**0.000**
Mixed (RL) (100w, 0.8H)	198	0.38	75.2	73	**0.971**
Mixed (RLC) (100w,0.8H,0.36uF)	**195.7**	**0.38**	**74.3**	**73**	**0.983**

Experiment 2: Series RLC resonant circuit.

Objectives:

- Determine the resonant frequency of a series RLC circuit.
- Measure the voltage and current at different frequencies to observe the resonance phenomenon.
- Compare the experimental results with the theoretical prediction

Figure 2: Circuit Diagram for Series RLC resonant circuit

OBSERVATION TABLE:

Table 2: Series RLC resonant circuit.

Voltage Across Resistor (V_R) vs. Frequency

Constants: Vin = 5V, R = 100Ω, L = 10mH, C = 0.1µF, Theoretical f_r = 1591.5 Hz

Frequency (Hz)	V_R (Volts)	Current (I = V_R / R, mA)	Phase Shift (θ)	Observations
500	1.2	12.0	Lagging (θ > 0°)	Dominated by inductive reactance (X_l).
1000	3.0	30.0	Slight lag	Approaching resonance.
1400	4.2	42.0	Near 0°	Lower cutoff frequency (f_1)
1600 (f_r)	5.0	50.0 (max)	0°	Resonance: Z = R, I = max
1800	4.2	42.0	Near 0°	Upper cutoff frequency (f_2)
2000	2.8	28.0	Leading (θ < 0°)	Dominated by capacitive reactance (X_c).
2500	1.5	15.0	Leading	Far from resonance.

Table 2:Voltage Across Resistor (V_R) vs. Frequency

Constants: Vin = 5V, R = 100Ω, L = 10mH, C = 0.1µF, Theoretical f_r = 1591.5 Hz

Peak Voltage/Current:

At f_r = 1600 Hz, V_R = Vin = 5V (maximum current, 50 mA).

- **Confirms resonance condition: XL=XC**

1. **Bandwidth (BW):**

- **BW = f_2 - f_1 = 1800 - 1400 = 400 Hz**

Phase Behavior:

- **Below f_r: Current lags voltage (inductive dominance).**

- **At f_r: In phase (θ = 0°).**
- **Above f_r: Current leads voltage (capacitive dominance).**

oltage Magnification:

- **V_L and V_C reached ~50V at resonance (Q = 10),**
- **though not shown in this table.**

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2000	2.8	28.0	Leading (θ < 0°)	Dominated by capacitive reactance (X_C).
2500	1.5	15.0	Leading	Far from resonance.

Table 3: Voltages at Resonance (f_r = 1600 Hz)

Parameter	Theoretical Value	Experimental Value	Remarks
Input Voltage (Vin)	5 V (constant)	5 V	Set by function generator
Voltage across R (V_R)	5 V	5 V	Matches V_in (Z = R at resonance).
Voltage across L (V_L)	50 V	49.8 V	Magnified due to Q-factor (Q = 10).
Voltage across C (V_C)	50 V	50.2 V	Equal and opposite to V_L (phasor).
Phase Angle (θ)	0°	~0° (observed)	Vin and I in phase at resonance.

V_L and V_C exceed V_in due to the **quality factor** (Q) of the circuit

Experimental values may slightly differ from theory due to:

- Component tolerances (L, C, R).
- Oscilloscope/probe calibration errors.

Phase relationship: At resonance, V_L and V_C cancel out (180° phase difference), leaving V_R = Vin.

9. CONCLUSION

The experiments conducted on RLC trainer demonstrated that, resonance occurred when the inductive and capacitive reactance canceled each other (XL=XC), resulting in minimum impedance (Z=R) and maximum current. The voltage across the inductor and capacitor magnified due to the quality factor (Q), while the phase angle between voltage and current became zero, indicating unity power factor.

Also, the power factor experiment emphasized the importance of improving efficiency in AC circuits. Inductive loads caused a lagging power factor, increasing reactive power and reducing system efficiency. By introducing a compensating capacitor, the power factor was corrected toward unity, minimizing losses and optimizing power delivery. Together, these experiments illustrated fundamental AC circuit principles in RLC resonance conditions.

RECOMMENDATION

To enhance future RLC trainer the following recommendations should be implemented. First, using precision instruments like digital LCR meters and calibrated oscilloscopes will improve measurement accuracy for component values and phase relationships. For resonance experiments, taking finer frequency steps near resonant peaks will allow more precise determination of quality factor (Q) and bandwidth, while in power factor studies, employing variable capacitor banks would better demonstrate compensation effects. Safety measures like current-limiting resistors and isolation transformers should be incorporated

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Thanks

For Your

Attention