MAXWELL INDUCTANCE CAPACITANCE BRIDGE

Group Project

PRESENTATION

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I also thank the laboratory staff for providing the necessary components and equipment required for the construction and testing of the bridge. Their assistance during the practical sessions was extremely helpful.

Finally, I wish to acknowledge my friends and classmates for their cooperation and support during the experiment and documentation.

INTRODUCTION:

In electrical engineering, AC bridges play an important role in the accurate measurement of inductance, capacitance, and resistance. Among the different AC bridges, the Maxwell Inductance–Capacitance Bridge is widely used for measuring the inductance and series resistance of medium-Q coils with high accuracy. Instead of using a standard inductor—which is difficult to construct with precision—this bridge uses a standard capacitor along with non-inductive resistors to achieve balance.

The Maxwell Bridge operates on the principle of impedance comparison. When the AC supply is applied and the bridge is balanced, the detector shows zero deflection. At this condition, the unknown inductance and its internal resistance can be calculated from simple balance equations. This makes the bridge highly suitable for laboratory experiments, calibration work, and educational purposes.

In this project, a practical Maxwell Inductance–Capacitance Bridge was constructed, and an unknown inductor from the lab was tested. Its inductance and series resistance were determined and compared with the known standard values to verify the accuracy of the setup.

PROJECT OBJECTIVES

Study: To understand the detailed working principle and balance equations of the Schering Bridge

Design: To design a functional and accurate circuit schematic for capacitance measurement

Implement: To create a compact and reliable circuit layout from the schematic

Test: To assemble the final circuit prototype and test its accuracy in measuring various unknown capacitors

MAXEWELL BRIDGE: THEORY

The Maxwell Inductance–Capacitance Bridge is an AC bridge used to determine the value of an unknown inductance and its internal series resistance by balancing it against a known standard capacitor and resistors. This bridge is preferred over other inductance bridges because a capacitor is more accurate, stable, and available compared to a standard inductor.

In a typical Maxwell L–C Bridge, the unknown inductor with resistance (L_1, R_1) is placed in one arm of the bridge. The opposite arm contains a standard capacitor (C_4) in parallel with a non-inductive resistor (R_4). The remaining two arms consist of resistors R_2 and R_3. An AC supply is connected across one pair of opposite junctions, and a detector (headphones, null detector, or AC voltmeter) is connected across the other diagonal.

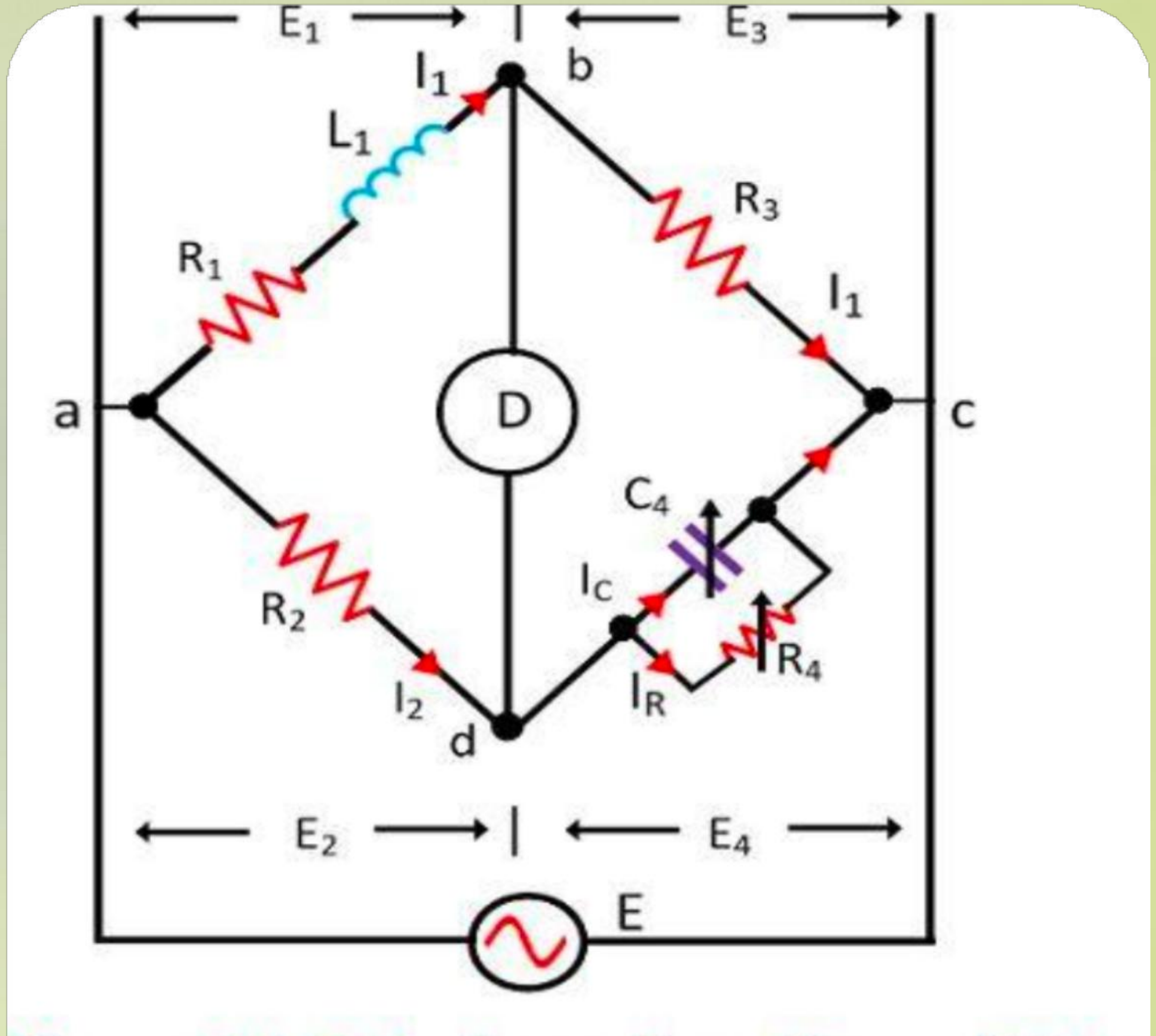
At balance, the impedance ratio in one pair of opposite arms equals the ratio in the other pair. By separating the real and imaginary components of the impedance equation, we obtain two independent balance conditions. These allow the simultaneous calculation of both the inductance L_1 and the series resistance R_1 of the unknown inductor.

The final balance equations are:

$L1 = R2 \times R3 \times C4$

$R1 = R2 \times R3 / R4$

These equations clearly show that the bridge provides accurate results and is largely independent of frequency, making it highly suitable for laboratory measurements and medium-Q inductors.



Maxewell's Inductance Capacitance Bridge

CIRCUIT DIAGRAM

The Maxwell Inductance-Capacitance Bridge consists of four arms arranged in a square network.

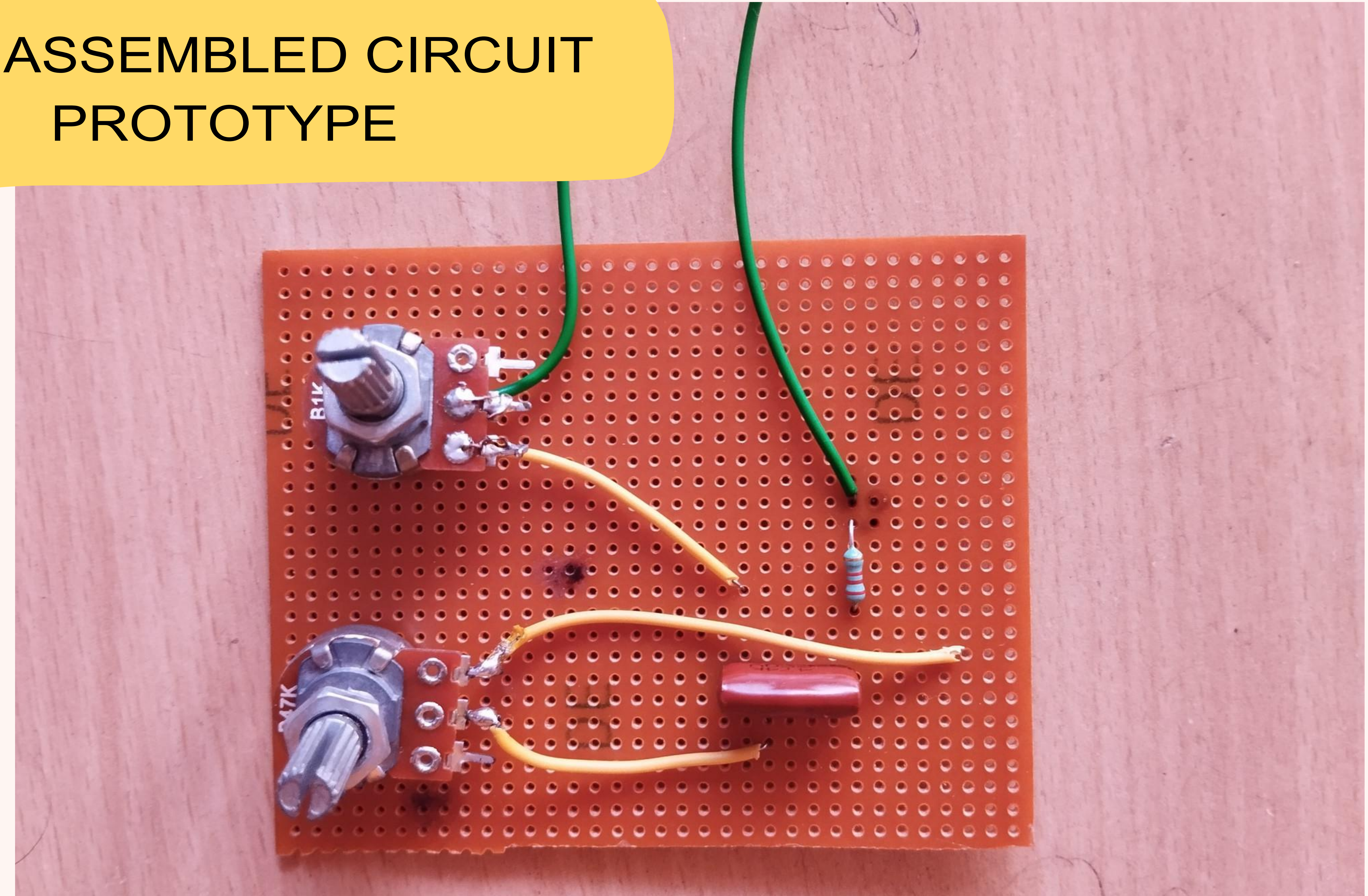
The unknown inductor (L_1 with its series resistance R_1) is placed in one arm. The opposite arm contains a resistor R_4 connected in parallel with a capacitor C_4. The remaining two arms contain non-inductive resistors R_2 and R_3.

The AC supply is connected across one pair of opposite corners of the bridge, and the detector is connected across the other pair.

WORKING PRINCIPLE

- The bridge works by balancing the impedance of the unknown inductive arm against the impedance of the parallel R-C arm. When the bridge is balanced, the voltage across the detector diagonal becomes zero, which means both the real and imaginary components of the network are matched.
- The key idea is that the unknown capacitor is compared with a standard (loss-free) capacitor, using resistors and variable capacitors to achieve a null (zero current) condition through the detector.
- The measurement process involves adjusting variable components until the phase and magnitude of the voltages in the opposite arms are balanced.

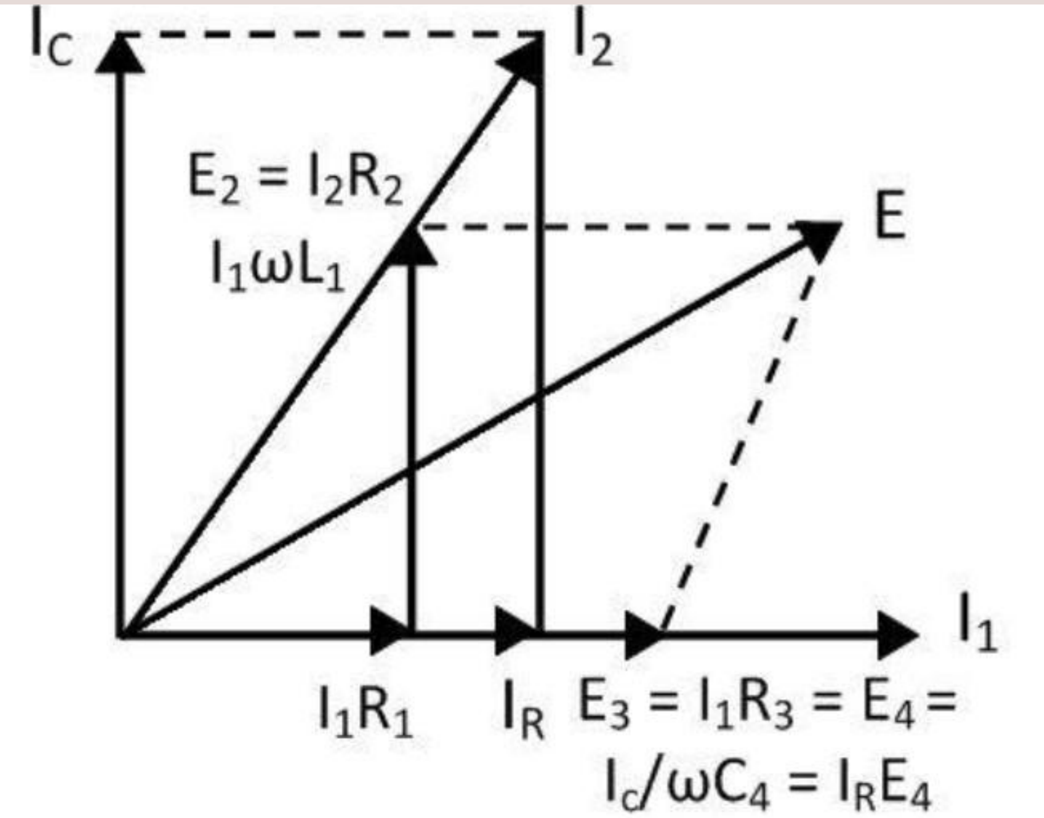
FINAL ASSEMBLED CIRCUIT PROTOTYPE



Phasor Diagram

The phasor diagram of the Maxwell Inductance–Capacitance Bridge represents the phase relationship between the voltages and currents in the inductive and capacitive arms at balance.

In the inductive arm containing the unknown inductor (L_1, R_1), the current lags behind the applied voltage due to the inductive reactance. In the parallel R_4–C_4 arm, the current through the capacitor leads the voltage, while the current through R_4 is in phase with the voltage. At balance, the combined effect of these currents and voltages is such that the potential difference between the detector points becomes zero



Phasor Diagram of Inductance Capacitance Bridge

Apparatus Required

The following components and instruments were used in the construction and testing of the Maxwell Inductance-Capacitance
Bridge:

1. Unknown Inductor (L_1) .Lab inductor of aapproximately 1 H inductance with internal series resistance.
2. Non-inductive Resistor R_3 (Fixed) :- 1 kΩ fixed resistor.
3. Fixed Resistor R_2- 1 kΩ potentiometer used for balancing.
4. Variable Resistor R_4 (Potentiometer) :-10 kΩ potentiometer connected in parallel with the capacitor.
5. Standard Capacitor C_4 :- 1 µF electrolytic capacitor (orange) connected across R_4.

PROCEDURE

1. Arrange all components on the board as per the circuit diagram.
2. Connect R_2 = 2.2 kΩ fixed and R_3 = 882Ω fixed in two opposite of the bridge.
3. Connect the unknown inductor L_1–R_1 in the third arm.
4. Connect R_4 (47 kΩ pot) in parallel with C_4 = 0.47 µF in the fourth arm.
5. Connect a Variac across one diagonal of the bridge (2.3V AC).
6. Connect a digital multimeter (AC voltage mode) across the detector diagonal.
7. Switch ON the AC supply and note the detector reading.
8. Since R_2 and R_3 are fixed, adjust only R_4 until the detector reading decreases.
9. Continue fine adjustments of R_4 until the multimeter shows the minimum AC voltage, indicating bridge balance.
10. Record the final balanced values:

R_2 = 2.2kΩ (fixed) ,R_3 = 882 Ω (fixed), R_4 = (balanced value) , C_4 = 0.47 µF

11. Use the balance equations: L1 = $R2*R3*C4$,R1 =$R2R3\ /R4$
12. Compare the calculated values of L_1 and R_1 with the actual measured values.

OBSERVATION AND CALCULATION:-

Observed Values at Balance

During the experiment, the bridge was balanced by adjusting only R_4 (keeping R_2 and R_3 fixed).
The following values were noted:

- R_2 (fixed resistor) = 2.2 kΩ
- R_3 (fixed resistor) = 882 Ω
- R_4 (balanced value, variable resistor) ≈ 27.14 kΩ
- C_4 (standard capacitor) = 0.47μF
- Measured resistance of inductor using multimeter:

$$R1\text{, measured} = 65.2\ \Omega$$

- Nameplate / known inductance of inductor:

$$L1\text{, known} \approx 1\ \text{H}$$

Bridge Balance Equations

For the Maxwell Inductance–Capacitance Bridge (with $R_4 \parallel C_4$):

$$L1 = R2 \times R3 \times C4$$

$$R1 = R2 \times R3/R4$$

CALCULATIONS

1. Calculation of Inductance $L1$

$$L1 = R2 \times R3 \times C4$$

Substitute the values:

$R2$ **= 2.2 kΩ= 22000 Ω**

$R3$ **= 882 Ω**

$C4$ **= 0.47** μF **= 0.47× 10−6** F **,**

$L1$ **= 22000 × 882× 0.47 × 10−6**

$L1$ **= 9119880 × 10−6 = 0.911 H**

⇒ **Calculated inductance:** $L1$**,calculated = 1 H This matches the known value of the inductor.**

2. Calculation of Series Resistance $R1$

$$R1 = R2 \times R3 \,/\, R4$$

Convert R4:

$R4$ **= 15.36 kΩ= 15360 Ω**

Now substitute:

R1 = 1000 × 1000 /

⇒ **Calculated resistance:** $R1$**,calculated ≈ 65.1 Ω**

ERROR:

$$Error = \frac{|L_{measured} - L_{calculated}|}{L_{calculated}} \times 100\%.$$

Error= |0.911 - 1| / 1 * 100

= 8.9 %

ADVANTAGES AND DISADVANTAGES:

ADVANTAGES:

1. **High accuracy**

The Maxwell Inductance–Capacitance Bridge uses a standard capacitor instead of a standard inductor. Capacitors are more stable, accurate and easily available, which improves the overall accuracy of the measurement.

2. **Simple balance equations**

The balance conditions -

L1 = $R2R3C4$, $R1$ = $R2R3$ /$R4$ are mathematically simple, making calculations easy and less error-prone.

3. **Frequency independence**

The expression for inductance $L1$does not explicitly depend on frequency (assuming ideal components), so small changes in frequency do not affect the result much.

4. **Suitable for medium-Q inductors**

The bridge gives reliable results for inductors of medium quality factor (Q), which are common in laboratories and practical circuits.

5. **Educational value**

The circuit clearly demonstrates AC bridge balancing, phasor relationships and impedance comparison, making it very useful for teaching and learning purposes.

DISADVANTAGES:

1. **Not suitable for very low-Q inductors**

For inductors with high losses (low Q), the accuracy of the bridge decreases and the null becomes less sharp.

2. **Requires a stable AC source**

A reasonably stable frequency and waveform are required from the function generator for accurate balancing.

3. **Adjustment of variable resistor**

The bridge requires careful and sometimes slow adjustment of R_4 to obtain a sharp null, which can be time-consuming.

4. **Component quality affects accuracy**

Any tolerance or drift in R_2, R_3, R_4 or C_4 directly affects the calculated values of L_1 and R_1, so good quality components are necessary.

APPLICATIONS

1. Measurement of Unknown Inductance The Maxwell Inductance-Capacitance Bridge is widely used for accurately determining the inductance of medium-Q coils in laboratories and industry.

2. Determination of Series Resistance of Inductors It provides both the inductance $L1$and the series resistance $R1$, which is important for analyzing the quality and performance of coils.

3. Calibration of Inductive Components. The bridge is used in calibration labs for testing standard inductors and comparing them with known capacitors and resistors.

4. Educational Demonstrations Because the bridge clearly illustrates AC bridge balancing, phasor relationships and impedance comparison, it is commonly used for teaching electrical measurement techniques.

APPLICATIONS

5. Quality Testing in Manufacturing Inductors used in power supplies, filters and RF circuits can be tested quality and tolerance using this bridge method

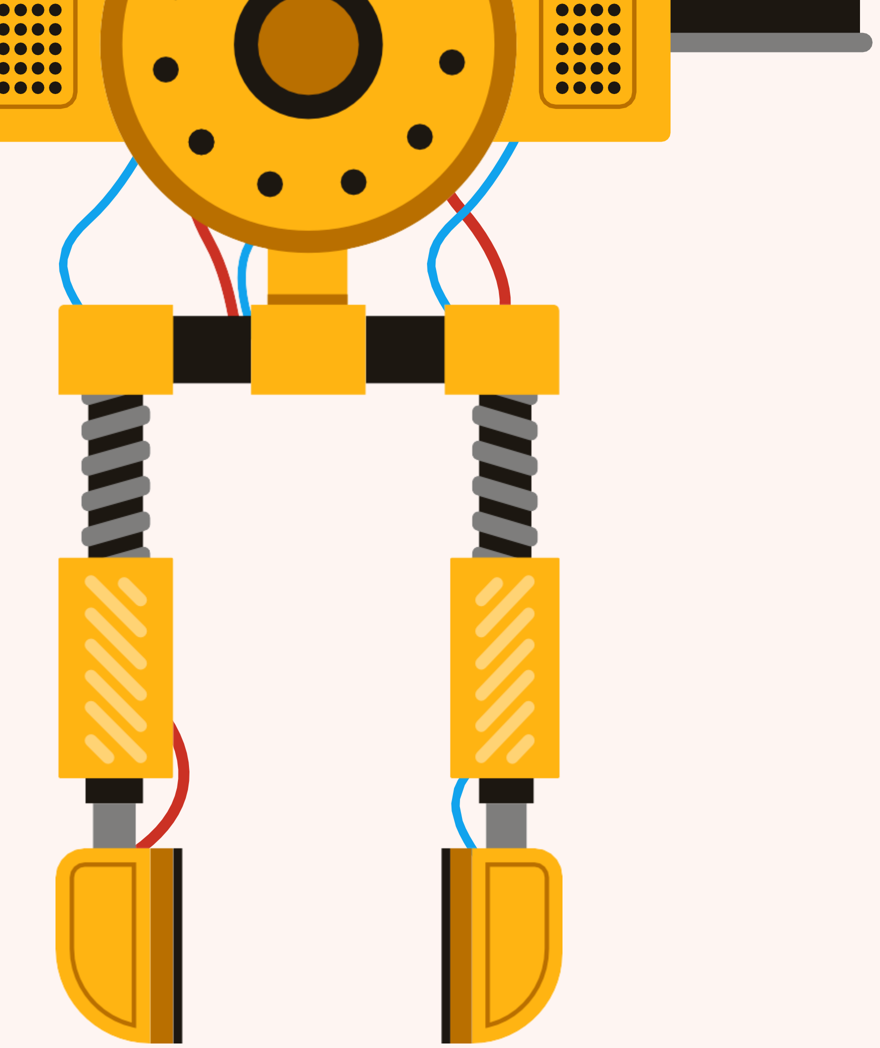
6. Research Experiments It is used in experiments involving inductive sensors, coil design and verification of theoretical AC circuit principles.

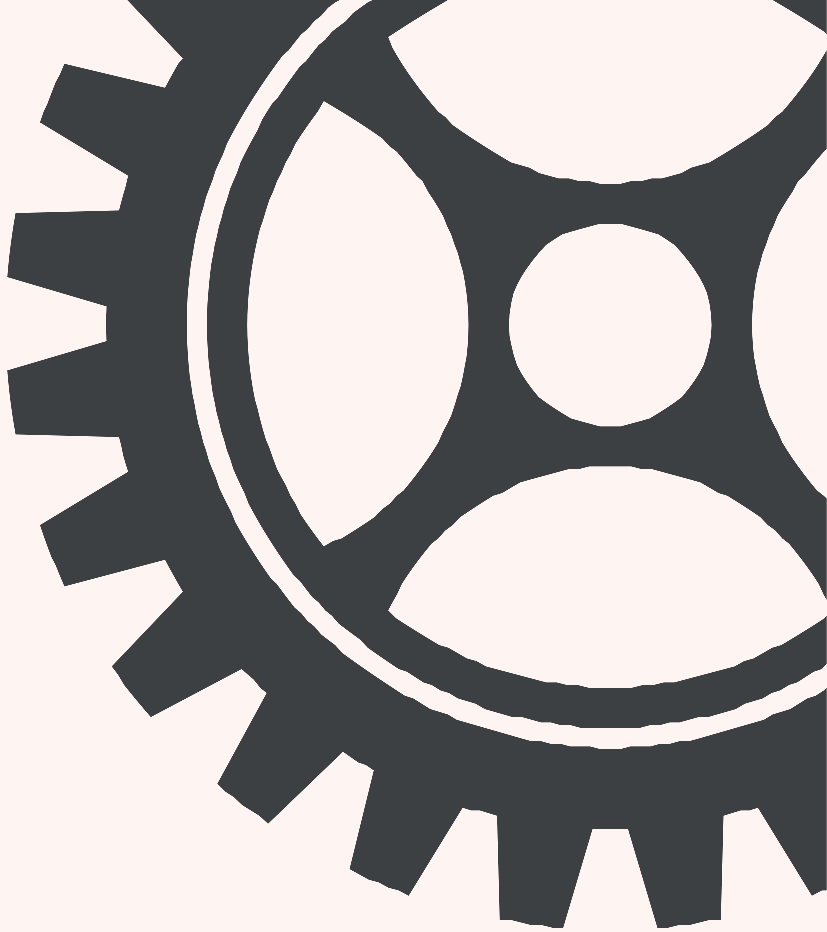
CONCLUSION:

In this project, a Maxwell Inductance–Capacitance Bridge was successfully constructed and used to determine the inductance and series resistance of an unknown inductor. By balancing the bridge using fixed resistors R_2 and R_3, a standard capacitor $C_4 = 0.470.47\mu F$, and a variable resistor R_4, the null point was accurately obtained using a digital multimeter.

The calculated values of the inductor were: • $L_1 = 1$ H • $R_1 \approx 65.2\ \Omega$ These values closely matched the measured readings ($R_1 = 65.18\ \Omega$, $L_1 \approx 0.911$ H), confirming the accuracy and effectiveness of the bridge. The experiment also provided a clear understanding of AC bridge balancing, impedance comparison, and practical measurement techniques.

Thus, the Maxwell Inductance–Capacitance Bridge proves to be a reliable and precise method for measuring inductance and internal resistance of medium-Q coils in laboratory conditions.





Thank You