Physics Lab

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Measurement of Resistor with Bridge and Kelvin Methods

November 3, 2024

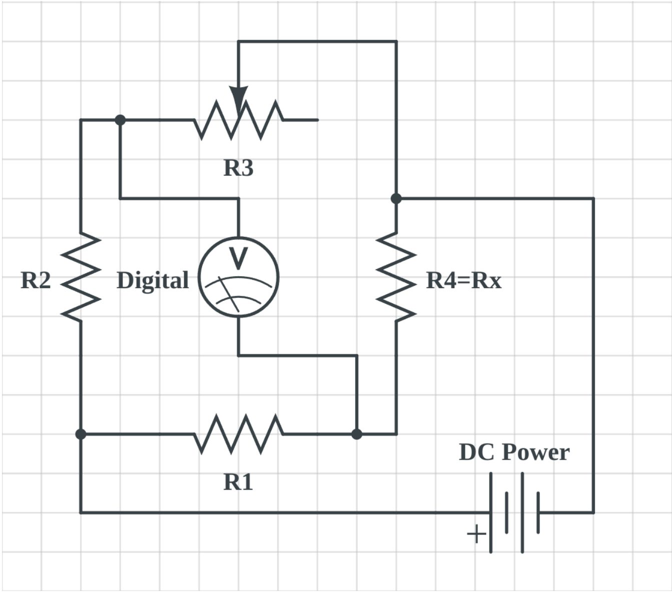
Overview

Here is book of Physics Lab experiment 4, Measurement of Resistor with Bridge and Kelvin (Double Bridge) Methods

Experiment Info

- **Purpose >** Studying the two methods and measure resistance of resistor
- **Necessary Equipment >** DC Power, Digital Voltmeter, 4 Resistors, Rheostat and Wires

Resistance : $R_x = \frac{R_1 \times R_3}{R_2}$



Measurement with Bridge and Kelvin Methods - Single Resistor

Steps

1. First we turn on the source DC Power and set it to $5V$.
2. Then we slowly moved slider as far as we could see exactly $0.00V$ on it.
3. In some cases multimeter can go to zero so we need to change other resistors resistance to reach the $0.00V$.
4. After that we measured each resistor with an Ohm Meter (Multimeter) outside of the circuit without connecting wires to them and wrote it down.
5. Then we calculated R_x via formula of $\frac{R_1 \times R_3}{R_2}$.

Resistance Measurement - Single Resistor Table

R_1	R_2	R_3	R_{x-real}	$R_{x-measured} = \frac{R_1 \times R_3}{R_2}$
$0.898k\Omega$	$1.008k\Omega$	$0.563k\Omega$	$0.507k\Omega$	$\alpha: 0.5016k\Omega$

Calculations of α :

$$R_{x-measured} = \frac{0.898k\Omega \times 0.563k\Omega}{1.008k\Omega} = 0.5016k\Omega$$

Resistance Measurement - Single Resistor Error Calculations

Error calculations are divided into 3 categories, absolute, relative and systematic errors and my personal task is to calculate errors of **first experiment** :

from absolute formula : $Absolute\ Error = |real\ value - measured\ value|$

We get this absolute error for α : $\varepsilon_{abs_\alpha} = |0.507k\Omega - 0.5016k\Omega| = 0.0054\Omega$

from relative formula : $Relative\ Error = \frac{|real\ value - measured\ value|}{real\ value}$

We get this absolute error for α : $\varepsilon_{rel_\alpha} = \frac{0.0054k\Omega}{0.507k\Omega} \approx 0.010651$

for systematic formula, We must do several mathematics operations :

1. Consider we have formula $R_x = \frac{R_1 \times R_3}{R_2}$.
2. Take the ln from both sides.
3. Take the differential from both sides.
4. Convert differentials to delta (Δ).
5. Convert every $-$ to $+$.
6. accuracy of **Analog Device** is equal to the lowest shown range on the device.
7. Error of **Analog Device** is equal to the lowest shown range on device multiplied by 0.5.
8. accuracy of **Digital Device** is equal to 10^{-x} where x is float level on the screen.
9. Error of **Digital Device** is equal to 10^{-x} where x is float level on the screen.

Now we can calculate systematic error using main formula :

$$Step\ 1: \quad R_x = \frac{R_1 \times R_3}{R_2}$$

for R_{x_α} :

$$Step\ 2: \quad ln(R_x) = ln(R_1) + ln(R_3) - ln(R_2)$$

$$Step\ 3: \quad \frac{dR_x}{R_x} = \frac{dR_1}{R_1} + \frac{dR_3}{R_3} - \frac{dR_2}{R_2}$$

$$Step\ 4: \quad \frac{\Delta R_x}{R_x} = \frac{\Delta R_1}{R_1} + \frac{\Delta R_3}{R_3} - \frac{\Delta R_2}{R_2}$$

$$Step\ 5: \quad \frac{\Delta R_x}{R_x} = \frac{\Delta R_1}{R_1} + \frac{\Delta R_3}{R_3} + \frac{\Delta R_2}{R_2}$$

$$Step\ 6\sim:\quad \Delta R_1 = \Delta R_2 = \Delta R_3 = 10^{-3}$$

$$Final: \quad \frac{\Delta R_x}{R_x} = \frac{10^{-3}k\Omega}{0.898k\Omega} + \frac{10^{-3}k\Omega}{1.008k\Omega} + \frac{10^{-3}k\Omega}{0.563k\Omega} \approx 0.00388$$

$$\Rightarrow \varepsilon_{sys} = 0.00388$$

Measurement with Bridge and Kelvin Methods - Parallel Resistors

Steps

1. The only change is to assemble R_x as parallel resistors of R_{x_1} and R_{x_2}.
2. Then we slowly moved slider as far as we could see exactly $0.00V$ on it.
3. After that we measured each resistor with an Ohm Meter (Multimeter) outside of the circuit without connecting wires to them and wrote it down.
4. Then we calculated R_x via formula of $\frac{R_{x_1} \times R_{x_2}}{R_{x_1} + R_{x_2}}$.

Resistance Measurement - Parallel Resistors Table

R_1	R_2	R_3	R_{x_1}	R_{x_2}	$R_{x-real} = \frac{R_{x_1} \times R_{x_2}}{R_{x_1} + R_{x_2}}$	$R_{x-measured} = \frac{R_1 \times R_3}{R_2}$
$1.107k\Omega$	$1.006k\Omega$	$0.560k\Omega$	$0.899k\Omega$	$2.150k\Omega$	$\alpha: 0.6339k\Omega$	$\beta: 0.6162k\Omega$

Calculations of α and β :

$$\alpha: R_{x-real} = \frac{0.899k\Omega \times 2.150k\Omega}{0.899k\Omega + 2.150k\Omega} \approx 0.6339k\Omega$$

$$\beta: R_{x-measured} = \frac{1.107k\Omega \times 0.560k\Omega}{1.006k\Omega} \approx 0.6162k\Omega$$

Resistance Measurement - Parallel Resistors Error Calculations

Error calculations are divided into 3 categories, absolute, relative and systematic errors and my personal task is to calculate errors of **first experiment** :

from absolute formula : $Absolute\ Error\ = |real\ value\ -\ measured\ value|$

We get this absolute error for α : $\varepsilon_{abs_{\alpha}} = |0.6339\Omega\ -\ 0.6162k\Omega| = 0.0177\Omega$

from relative formula : $Relative\ Error\ = \frac{|real\ value - measured\ value|}{real\ value}$

We get this absolute error for α : $\varepsilon_{rel_{\alpha}} = \frac{0.0177k\Omega}{0.6339k\Omega} \approx 0.02792$

for systematic formula, We must do several mathematics operations :

10. Consider we have formula $R_x = \frac{R_1 \times R_3}{R_2}$.
11. Take the ln from both sides.
12. Take the differential from both sides.
13. Convert differentials to delta (Δ).
14. Convert every $-$ to $+$.
15. accuracy of **Analog Device** is equal to the lowest shown range on the device.
16. Error of **Analog Device** is equal to the lowest shown range on device multiplied by 0.5.
17. accuracy of **Digital Device** is equal to 10^{-x} where x is float level on the screen.
18. Error of **Digital Device** is equal to 10^{-x} where x is float level on the screen.

Now we can calculate systematic error using main formula :

$$Step\ 1: \qquad R_x = \frac{R_1 \times R_3}{R_2}$$

for $R_{x_{\alpha}}$:

$$Step\ 2: \qquad ln(R_x) = ln(R_1) + ln(R_3) - ln(R_2)$$

$$Step\ 3: \quad \frac{dR_x}{R_x} = \frac{dR_1}{R_1} + \frac{dR_3}{R_3} - \frac{dR_2}{R_2}$$

$$Step\ 4: \quad \frac{\Delta R_x}{R_x} = \frac{\Delta R_1}{R_1} + \frac{\Delta R_3}{R_3} - \frac{\Delta R_2}{R_2}$$

$$Step\ 5: \quad \frac{\Delta R_x}{R_x} = \frac{\Delta R_1}{R_1} + \frac{\Delta R_3}{R_3} + \frac{\Delta R_2}{R_2}$$

$$Step\ 6\sim: \quad \Delta R_1 = \Delta R_2 = \Delta R_3 = 10^{-3}$$

$$Final: \quad \frac{\Delta R_x}{R_x} = \frac{10^{-3}k\Omega}{1.107k\Omega} + \frac{10^{-3}k\Omega}{1.006k\Omega} + \frac{10^{-3}k\Omega}{0.560k\Omega} \approx 0.00368$$

$$\Rightarrow \varepsilon_{sys} = 0.00368$$

Measurement with Bridge and Kelvin Methods - Series Resistors

Steps

1. The only change is to assemble R_x as series resistors of R_{x_1} and R_{x_2}.
2. Then we slowly moved slider as far as we could see exactly $0.00V$ on it.
3. After that we measured each resistor with an Ohm Meter (Multimeter) outside of the circuit without connecting wires to them and wrote it down.
4. Then we calculated R_x via formula of $R_{x_1} + R_{x_2}$.

Calculations are in Next Page

Resistance Measurement - Series Resistors Table

R_1	R_2	R_3	R_{x_1}	R_{x_2}	$R_{x-real} = R_{x_1} + R_{x_2}$	$R_{x-measured} = \frac{R_1 \times R_3}{R_2}$
$4.61k\Omega$	$1.005k\Omega$	$0.563k\Omega$	$0.399k\Omega$	$2.20k\Omega$	$\alpha:\ 2.5990k\Omega$	$\beta:\ 2.5825k\Omega$

Calculations of α and β :

$$\alpha:\ R_{x-real} = 0.399k\Omega + 2.20k\Omega \approx 2.5990k\Omega$$

$$\beta:\ R_{x-measured} = \frac{4.61k\Omega \times 0.563k\Omega}{1.005k\Omega} \approx 2.5825k\Omega$$

Resistance Measurement - Series Resistors Error Calculations

Error calculations are divided into 3 categories, absolute, relative and systematic errors and my personal task is to calculate errors of **first experiment** :

from absolute formula : $Absolute\ Error = |real\ value - measured\ value|$

We get this absolute error for α : $\varepsilon_{abs_\alpha} = |2.5990\Omega - 2.5825k\Omega| = 0.0165\Omega$

from relative formula : $Relative\ Error = \frac{|real\ value - measured\ value|}{real\ value}$

We get this absolute error for α : $\varepsilon_{rel_\alpha} = \frac{0.0165k\Omega}{2.5990k\Omega} \approx 0.00635$

for systematic formula, We must do several mathematics operations :

19. Consider we have formula $R_x = \frac{R_1 \times R_3}{R_2}$.
20. Take the ln from both sides.
21. Take the differential from both sides.
22. Convert differentials to delta (Δ).
23. Convert every $-$ to $+$.

24. accuracy of **Analog Device** is equal to the lowest shown range on the device.
25. Error of **Analog Device** is equal to the lowest shown range on device multiplied by 0.5.
26. accuracy of **Digital Device** is equal to 10^{-x} where x is float level on the screen.
27. Error of **Digital Device** is equal to 10^{-x} where x is float level on the screen.

Now we can calculate systematic error using main formula :

$$Step\ 1: \quad R_x = \frac{R_1 \times R_3}{R_2}$$

for R_{x_α} :

$$Step\ 2: \quad ln(R_x) = ln(R_1) + ln(R_3) - ln(R_2)$$

$$Step\ 3: \quad \frac{dR_x}{R_x} = \frac{dR_1}{R_1} + \frac{dR_3}{R_3} - \frac{dR_2}{R_2}$$

$$Step\ 4: \quad \frac{\Delta R_x}{R_x} = \frac{\Delta R_1}{R_1} + \frac{\Delta R_3}{R_3} - \frac{\Delta R_2}{R_2}$$

$$Step\ 5: \quad \frac{\Delta R_x}{R_x} = \frac{\Delta R_1}{R_1} + \frac{\Delta R_3}{R_3} + \frac{\Delta R_2}{R_2}$$

$$Step\ 6\sim: \quad \Delta R_1 = 10^{-2} \quad , \quad \Delta R_2 = \Delta R_3 = 10^{-3}$$

$$Final: \quad \frac{\Delta R_x}{R_x} = \frac{10^{-2} k\Omega}{4.61 k\Omega} + \frac{10^{-3} k\Omega}{1.005 k\Omega} + \frac{10^{-3} k\Omega}{0.563 k\Omega} \approx 0.00494$$

$$\Rightarrow \varepsilon_{sys} = 0.00494$$