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Understanding electrical circuits is fundamental in both academic and practical applications of electronics and electrical engineering. When a voltage source supplies power to a series combination of resistors, analyzing the circuit involves calculating the total resistance, current flow, and voltage distribution across each component. In this article, we explore a specific scenario where a 120-volt supply provides power to a series circuit consisting of a resistor with resistance 10-12 ohms, another resistor with resistance 5-2 ohms, and an unknown resistor. We will delve into the principles governing such circuits, techniques for analyzing them, and how to determine the unknown resistor's value based on observed data.

Understanding Series Circuits

What Is a Series Circuit?

A series circuit is a configuration where electrical components are connected end-to-end in a single path for current to flow. The key characteristics of series circuits include:

- Single Path: Current flows through each component sequentially.
- Shared Current: The same current passes through all components.
- Voltage Division: The total voltage supplied is divided among the components based on their resistances.
- Total Resistance: Sum of individual resistances, $(R_{\text{total}} = R_1 + R_2 + R_3 + \dots)$

Importance in Electrical Design

Series circuits are fundamental in understanding how voltage and current behave in more complex systems. They are used in applications such as:

- Decorative string lights
- Series-connected sensors
- Basic educational demonstrations

Analyzing the Circuit with Known Resistances

Given Data

The circuit in question involves:

- A voltage source $(V_s = 120\text{V})$

- Resistors:

1. $(R_1 = 10 \text{ to } 12\,\Omega)$ (assumed as a range due to uncertainty)

2. $(R_2 = 5 \text{ to } 2\,\Omega)$ (also a range)

3. $(R_{\text{unknown}} = R_x)$

Approach to Analysis

To analyze this circuit, the following steps are essential:

1. Determine the total resistance based on the resistor ranges.
2. Calculate the current flowing through the circuit.
3. Find the voltage across each resistor.
4. Use the data to infer the unknown resistor value (R_x) .

Calculating Total Resistance in Series Circuits

Range-Based Resistance Calculations

Since some resistors are specified with ranges, the total resistance will also vary within calculated bounds.

- Minimum Total Resistance:

$$R_{\text{total}_{\text{min}}} = R_{1_{\text{min}}} + R_{2_{\text{min}}} + R_x$$

- Maximum Total Resistance:

$$R_{\text{total}_{\text{max}}} = R_{1_{\text{max}}} + R_{2_{\text{max}}} + R_x$$

Assuming (R_x) is unknown, we analyze the circuit for various plausible values of (R_x) to determine its possible range.

Calculating Current in the Circuit

Using Ohm's Law:

$$I = \frac{V_s}{R_{\text{total}}}$$

where (R_{total}) is the sum of all resistances in series.

Depending on the resistance values, the current will range accordingly:

- For minimum resistance, current will be maximum.
- For maximum resistance, current will be minimum.

Voltage Distribution Across Resistors

Applying Ohm's Law again:

$$V_R = I \times R$$

The voltage across each resistor depends on the total current and its resistance. By analyzing voltage drops, one can identify the unknown resistor's value if certain voltages are measured.

Determining the Unknown Resistance (R_x)

1. Measure the voltage across known resistors when the circuit is operational.
2. Calculate the current using total voltage and the total resistance (if resistance ranges are known).
3. Apply voltage division principles to solve for (R_x) using the measured voltages and known resistor values.

Example Calculation:

Suppose the voltage across (R_1) (say, $10\ \Omega$) is measured as 60 V, and across (R_2) as 30 V. Using Ohm's Law:

$$I = \frac{V_{R_1}}{R_1} = \frac{60\text{ V}}{10\ \Omega} = 6\text{ A}$$

\]

Similarly, check across (R_2) :

\[

$$I = \frac{30\text{V}}{5\Omega} = 6\text{A}$$

\]

Both currents match, confirming the series connection.

Now, total current:

\[

$$I_{\text{total}} = 6\text{A}$$

\]

Total resistance:

\[

$$R_{\text{total}} = \frac{V_{\text{s}}}{I} = \frac{120\text{V}}{6\text{A}} = 20\Omega$$

\]

Sum of known resistors:

\[

$$R_{\text{known}} = R_1 + R_2 = 10\Omega + 5\Omega = 15\Omega$$

\]

Thus, the unknown resistor:

\[

$$R_x = R_{\text{total}} - R_{\text{known}} = 20\Omega - 15\Omega = 5\Omega$$

\]

This process demonstrates how measured voltages and currents can help determine the unknown resistance.

Applications and Practical Considerations

Designing Circuits with Unknown Components

When designing or troubleshooting circuits:

- Use voltage and current measurements to infer unknown component values.
- Ensure the circuit operates within safe limits for voltage and current.
- Consider resistor tolerances, which can affect measurements and calculations.

Safety Precautions

- Always disconnect power before modifying circuits.
- Use appropriate measuring instruments, such as multimeters, for voltage, current, and resistance.
- Be aware of resistor power ratings to prevent overheating.

Summary of Key Points

- Series circuits have a simple additive resistance model.
- The total current is determined by the total resistance and supply voltage.
- Voltage distribution across components follows Ohm's Law.
- Ranges in resistor values introduce variability in circuit analysis.
- Measuring voltages and currents enables the calculation of unknown resistances.
- Practical circuit analysis combines theoretical calculations with empirical data for accurate component determination.

Conclusion

Analyzing a series circuit supplied by a 120 V source with known and unknown resistors involves understanding fundamental principles of electrical resistance, Ohm's Law, and voltage division. Whether you're designing new circuits or troubleshooting existing ones, these techniques are invaluable for identifying unknown component values, ensuring circuit safety, and optimizing performance. By carefully measuring voltages and currents and applying the principles discussed, engineers and technicians can accurately determine unknown resistor values and understand the behavior of complex electrical systems.

Optimized for SEO Keywords:

- Series circuit analysis
- 120V power supply
- Resistor resistance calculation
- Unknown resistor determination
- Voltage division in series circuits
- Electrical circuit troubleshooting
- Ohm's Law applications
- Resistance measurement techniques
- Series resistor ranges
- Circuit design and analysis

Frequently Asked Questions

What is the total resistance in the series circuit if the unknown resistor is 8 ohms?

The total resistance is the sum of all resistances: $10\text{-}12\Omega$ (assuming 11Ω average), $5\text{-}2\Omega$ (3Ω), and 8Ω . So, total resistance $\approx 11\Omega + 3\Omega + 8\Omega = 22\Omega$.

How much current flows through the series circuit with a 120 V source and the given resistances?

Using Ohm's Law, $I = V / R_{\text{total}}$. If the total resistance is approximately 22Ω , then $I = 120\text{V} / 22\Omega \approx 5.45\text{A}$.

What is the voltage drop across each resistor in the series circuit?

Voltage drop across each resistor is proportional to its resistance: $V = IR$. For each resistor, multiply its resistance by the total current ($\sim 5.45\text{A}$). For example, across the 10Ω resistor: $V \approx 10\Omega \cdot 5.45\text{A} \approx 54.5\text{V}$.

If the unknown resistor's resistance increases, how does that affect the total current in the circuit?

An increase in the unknown resistor's resistance raises the total resistance, thereby decreasing the total current in the circuit, according to Ohm's Law.

How can you determine the value of the unknown resistor in the series circuit if you know the total voltage and the individual voltage drops across known resistors?

Sum the voltages across the known resistors and subtract from the total voltage (120V) to find the voltage across the unknown resistor. Then, use Ohm's Law ($V = IR$) with the current to find its resistance: $R_{\text{unknown}} = V_{\text{unknown}} / I$.

Additional Resources

A Source Supplies 120 V To The Series Combination Of A 10-12 Resistance, A 5-2 Resistance, And An Unknown: An In-Depth Investigation

In the realm of electrical engineering, understanding how voltage sources interact with various resistor configurations is fundamental. One intriguing scenario involves a power source supplying a fixed voltage to a series combination of resistors, one of which has an unknown resistance value. This situation not only tests foundational principles of circuit analysis but also exemplifies real-world troubleshooting and design challenges. In this investigative article, we delve into the specifics of a circuit where a 120-volt source feeds a series circuit consisting of a known resistor ($10\text{-}12\Omega$),

another known resistor (5-2 Ω), and an unknown resistor. We will analyze the circuit comprehensively, explore the methods to determine the unknown resistance, and discuss potential applications and implications.

Understanding the Circuit Configuration

Basic Description and Assumptions

The circuit under investigation involves:

- A 120-volt DC power source (assumed direct current for simplicity unless otherwise specified).
- A series connection of three resistors:
 - Resistor R_1 with a resistance value in the range of 10-12 Ω .
 - Resistor R_2 with a resistance value in the range of 5-2 Ω .
 - An unknown resistor R_x , with an unknown resistance value.

The series configuration implies that the same current flows through all components, and the total voltage divides among them.

Clarifying the Resistance Ranges

- R_1 : 10-12 Ω (e.g., 10 Ω , 11 Ω , or 12 Ω)
- R_2 : 5-2 Ω (e.g., 5 Ω , 4 Ω , 3 Ω , or 2 Ω)

Given these ranges, the resistor values could be specific or approximate, which influences the analysis.

Analytical Approach to the Circuit

Fundamental Principles

The analysis hinges on Ohm's law and series circuit principles:

- Total Resistance (R_{total}): $R_1 + R_2 + R_x$
- Total Current (I): $I = V_{\text{source}} / R_{\text{total}}$
- Voltage Drop Across Each Resistor (V_1, V_2, V_x): $V_n = I \times R_n$

To determine R_x , we need additional data such as:

- Voltage measurements across known resistors
- Current measurements
- Power dissipation

In the absence of such data, the problem becomes a parameter estimation challenge, which we will explore.

Deep Dive: Methods to Determine the Unknown Resistance

Method 1: Using Voltage Measurements

Suppose one measures the voltage drops across R_1 and R_2 :

- V_1 = Voltage across R_1
- V_2 = Voltage across R_2
- V_x = Voltage across R_x

Given the total voltage $V_{\text{total}} = 120 \text{ V}$, the sum:

$$V_{\text{total}} = V_1 + V_2 + V_x$$

Knowing V_1 and V_2 , R_x can be deduced:

$$R_x = (V_x / I) = V_x / (V_{\text{total}} / R_{\text{total}})$$

But since R_{total} involves R_x , iterative approaches or additional measurements are necessary.

Method 2: Measuring Total Current

If a current meter is connected in series with the circuit, then:

$$I = V_{\text{total}} / R_{\text{total}}$$

Knowing I , and measuring the voltage drop across the known resistors, R_1 and R_2 , R_x can be isolated:

- Step 1: Measure I
- Step 2: Compute $R_{\text{total}} = V_{\text{total}} / I$
- Step 3: Calculate $R_x = R_{\text{total}} - R_1 - R_2$

This method assumes precise measurement of R_1 and R_2 or their known values.

Practical Case Study: Hypothetical Data and Analysis

Suppose the following measurements are obtained:

- Voltage across R_1 (V_1): 50 V
- Voltage across R_2 (V_2): 30 V
- Remaining voltage across R_x (V_x): 40 V
- Total supply voltage (V_{total}): 120 V

And the known resistor ranges:

- R_1 : approximately 11 Ω
- R_2 : approximately 3.5 Ω

Calculating the Current

- Using R_1 : $I_1 = V_1 / R_1 \approx 50 \text{ V} / 11 \Omega \approx 4.55 \text{ A}$
- Using R_2 : $I_2 = V_2 / R_2 \approx 30 \text{ V} / 3.5 \Omega \approx 8.57 \text{ A}$

Discrepancy indicates that the resistors' actual values might differ from their ranges, or the voltage measurements are approximate. For an accurate analysis, precise resistor values are necessary.

Assuming the current is uniform in a series circuit, the more accurate current estimate would be based on the resistor with the highest voltage drop and known resistance:

- $I \approx V_1 / R_1 \approx 4.55 \text{ A}$

Now, calculating R_x :

- $R_x = V_x / I \approx 40 \text{ V} / 4.55 \text{ A} \approx 8.79 \Omega$

This suggests the unknown resistor R_x has a resistance close to 8.8Ω .

Challenges and Considerations in Real-World Applications

Variability of Resistor Values

Resistors from manufacturing tolerances often vary by $\pm 5\%$ or more. This variability affects calculations and necessitates precise measurements.

Measurement Accuracy

Voltage and current measurement instruments must be accurate and properly calibrated to avoid errors that could significantly impact the estimation of R_x .

Power Dissipation and Safety

High currents through resistors lead to heat dissipation. Ensuring resistors can handle the power ($P = I^2 \times R$) is vital for safety and reliability.

Potential Applications and Implications

Troubleshooting and Circuit Design

Understanding how unknown resistances behave in series circuits is crucial for troubleshooting electrical systems, designing sensors, and developing complex circuitry.

Educational Value

This scenario serves as an excellent teaching aid for students to practice circuit analysis, measurement techniques, and problem-solving skills.

Real-World Analogues

In practice, components often have tolerances, and engineers must infer values through indirect measurements. This scenario mirrors real-world situations where component datasheets or markings are missing, and estimation becomes necessary.

Conclusion

The investigation of a source supplying 120 V to a series combination of a 10-12 Ω resistor, a 5-2 Ω resistor, and an unknown resistor encapsulates core principles of electrical circuit analysis, measurement techniques, and practical problem-solving. Through systematic measurement, careful analysis, and an understanding of fundamental laws, it is possible to infer the unknown resistance with reasonable accuracy.

This analysis underscores the importance of precise measurement tools, awareness of component tolerances, and methodical approaches in electrical engineering tasks. Whether in designing new circuits, troubleshooting existing systems, or educational demonstrations, the ability to deduce unknown parameters from partial data remains an essential skill.

In future investigations, incorporating additional measurement data such as current readings, power dissipation, or using instrumentation like oscilloscopes could further refine the estimation process, leading to more accurate and reliable results. As technology advances, automated systems may even perform such analyses instantly, but the foundational understanding remains indispensable for engineers and technicians alike.

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About the Author

Jane Doe is an electrical engineering researcher with over a decade of experience in circuit analysis, instrumentation, and systems troubleshooting. She specializes in educational content and practical applications of electrical principles.

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