In A Parallel Circuit, Determine The Value Of R2 In Ohms Suchthat The Current Is 5 Times The Current

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Understanding how to analyze and design electrical circuits is fundamental in electronics and electrical engineering. One common problem involves calculating the resistance needed in a parallel circuit to achieve a specific current ratio. Specifically, if you want the current flowing through one branch to be five times the current through another, determining the correct resistance for that branch becomes essential. In this article, we will explore how to find the value of R2 in ohms such that the current in R2 is five times the current in another resistor R1 within a parallel circuit configuration.

Fundamentals of Parallel Circuits

Before delving into the calculations, it’s important to understand the basics of parallel circuits.

What is a Parallel Circuit?

A parallel circuit is an electrical circuit where multiple components are connected across the same voltage source. This means each component has its own direct path to the voltage source, and the total current divides among the branches.

Key Characteristics of Parallel Circuits

- Voltage across each branch is the same.
- The total current is the sum of the currents through each branch.
- Resistances are connected in parallel, affecting the total equivalent resistance.

Understanding the Current Ratio in Parallel Circuits

In a parallel circuit with resistors R1 and R2 connected across a voltage source V, the currents through R1 and R2 (denoted I1 and I2 respectively) depend on their resistances. Ohm's Law states that:

$$ I = \frac{V}{R} $$

Therefore:

$$ I_1 = \frac{V}{R_1} $$
$$ I_2 = \frac{V}{R_2} $$

Given this, the current ratio is:

$$ \frac{I_2}{I_1} = \frac{\frac{V}{R_2}}{\frac{V}{R_1}} = \frac{R_1}{R_2} $$

This simple relationship is crucial for solving the problem of determining R2 when the current ratio is specified.

Problem Statement: Finding R2 for a 5:1 Current Ratio

Suppose we have a parallel circuit with a fixed voltage source V, and resistors R1 and R2 connected in parallel. We are told that the current through R2, I2, should be five times the current through R1, I1. Formally:

$$ I_2 = 5 \times I_1 $$

Given this, the goal is to determine the value of R2 in ohms.

Step-by-Step Solution Process

Let's break down the calculation into manageable steps.

Step 1: Express the Current Ratio

From the earlier formulas:

$$ I_1 = \frac{V}{R_1} $$
$$ I_2 = \frac{V}{R_2} $$

Given that I2 is five times I1:

$$ \frac{V}{R_2} = 5 \times \frac{V}{R_1} $$

Since V appears on both sides, it cancels out:

$$ \frac{1}{R_2} = 5 \times \frac{1}{R_1} $$

This simplifies to:

$$R_2 = \frac{R_1}{5}$$

Key insight: The resistance R2 must be one-fifth of R1 for the current through R2 to be five times that through R1.

Step 2: Determine R2 Based on Known R1

The calculation hinges on knowing R1. If R1's value is known, R2 can be directly calculated:

$$R_2 = \frac{R_1}{5}$$

Example:

- If R1 = 25 Ω, then:

$$R_2 = \frac{25}{5} = 5\, \Omega$$

- If R1 is unknown, additional information such as the voltage source V or the current I1 can be used to find R1.

Incorporating Voltage and Current Values

To make the calculation more practical, let's consider an example with actual voltage and current values.

Example Scenario

Suppose:

- Voltage, V = 12 V
- Current through R1, I1 = 1 A (initial assumption)

Calculate R1:

$$R_1 = \frac{V}{I_1} = \frac{12\, \text{V}}{1\, \text{A}} = 12\, \Omega$$

Now, since I2 should be five times I1:

$$I_2 = 5\, \text{A}$$

Calculate R2:

$$R_2 = \frac{V}{I_2} = \frac{12\, \text{V}}{5\, \text{A}} = 2.4\, \Omega$$

Alternatively, using the resistance ratio approach:

$$ R_2 = \frac{R_1}{5} = \frac{12\, \Omega}{5} = 2.4\, \Omega $$

This confirms the earlier calculation.

Additional Considerations in Circuit Design

While the above calculations assume ideal conditions, real-world applications often involve additional factors.

1. Power Ratings

Ensure that the resistors used can handle the power dissipation:

$$ P = I^2 \times R $$

For R2 with I2 = 5 A and R2 = 2.4 Ω:

$$ P = (5)^2 \times 2.4 = 25 \times 2.4 = 60\, \text{W} $$

Select resistors with power ratings exceeding this value for safety and durability.

2. Tolerance and Resistance Variability

Resistors come with tolerance levels (e.g., ±5%), which can affect current ratios. Precision resistors may be required for sensitive applications.

3. Voltage Source Limitations

Ensure the voltage source can supply the total current without exceeding its limits.

Summary and Practical Tips

- The key to solving for R2 in a parallel circuit with a specified current ratio lies in understanding the inverse relationship between resistance and current.
- The fundamental formula is:

$$ R_2 = \frac{R_1}{\text{Current Ratio}} $$

- For a current five times that of another branch, R2 must be one-fifth of R1.
- Always verify resistor power ratings and tolerance levels in real-world applications.
- Adjust calculations based on actual voltage and current measurements for precise circuit design.

Conclusion

Determining the value of R2 in ohms such that the current through it is five times that through R1 in a parallel circuit is straightforward when understanding the relationship between resistance and current. By leveraging Ohm's Law and the principles of parallel circuits, you can quickly derive:

$$R_2 = \frac{R_1}{5}$$

This relationship simplifies circuit analysis and design, enabling engineers and enthusiasts to tailor their circuits for specific current distributions efficiently. Whether designing a sensor network, power distribution system, or experimental setup, mastering these calculations ensures optimal performance and safety.

Remember, always consider practical factors such as resistor power ratings, tolerances, and source limitations to ensure your circuit operates reliably under real-world conditions.

Frequently Asked Questions

In a parallel circuit where the total current is five times the current through R1, how can I determine the value of R2?

You can use the relationship I_total = 5 I_R1 and apply the parallel circuit current formulas to solve for R2, considering the total voltage and the known R1 value.

What is the formula to find R2 in a parallel circuit if the total current is five times the current through R1?

First, express I_R1 = V / R1, and total current I_total = 5 I_R1 = 5 V / R1. Since I_total = V / R_total, then R_total = V / I_total. Knowing R_total and R1, R2 can be found using 1/R_total = 1/R1 + 1/R2, leading to R2 = 1 / (1/R_total - 1/R1).

If the voltage across the parallel circuit is 12V, R1 is 4Ω, and the total current is five times the current through R1, what is R2?

First, find I_R1 = 12V / 4Ω = 3A. Total current I_total = 5 3A = 15A. Then, R_total = V / I_total = 12V / 15A = 0.8Ω. Using 1/R_total = 1/R1 + 1/R2, we get 1/0.8 = 1/4 + 1/R2, so 1/R2 = 1/0.8 - 1/4 = 1.25 - 0.25 = 1.0. Therefore, R2 = 1Ω.

How does the relationship between current through R1 and R2 affect the calculation of R2 in this parallel circuit?

Since the total current is five times the current through R1, it indicates that R2 carries the remaining current, and this ratio allows us to set up equations relating R2 to R1 and the total current, enabling its calculation using parallel resistance formulas.

Can you provide a step-by-step method to determine R2 in a parallel circuit where the total current is five times that through R1?

Yes. Step 1: Find I_R1 = V / R1. Step 2: Calculate I_total = 5 I_R1. Step 3: Determine R_total = V / I_total. Step 4: Use the formula 1/R_total = 1/R1 + 1/R2 to solve for R2: R2 = 1 / (1/R_total - 1/R1).

Additional Resources

In A Parallel Circuit, Determine The Value Of R2 In Ohms Such That The Current Is 5 Times The Current

Understanding electrical circuits is fundamental to both academic pursuits and practical applications in engineering and electronics. Among the various types of circuits, parallel circuits are particularly significant because of their unique properties, such as constant voltage across components and the ability to control current flow through individual branches. A common problem faced by students and professionals alike involves analyzing these circuits to determine specific resistor values based on current and voltage conditions. One intriguing question is: In a parallel circuit, how do you determine the value of R_2 in ohms such that the current flowing through it is five times the total current?

This article explores that question in depth, providing a comprehensive guide to understanding the underlying principles, deriving the necessary formulas, and solving for R_2 with clarity and precision.

Understanding Parallel Circuits and Current Distribution

Fundamental Concepts of Parallel Circuits

A parallel circuit consists of multiple components connected across the same voltage source, creating multiple paths for current to flow. The key features include:

- Common Voltage: All components in parallel experience the same voltage across their terminals.
- Individual Currents: The total current supplied by the source divides among the branches, with each branch's current depending on its resistance.
- Equivalent Resistance: The overall resistance of a parallel circuit is less than the smallest individual resistance, calculated as:

$$
\frac{1}{R_{eq}} = \sum_{i} \frac{1}{R_i}
$$

where R_i is the resistance of each branch.

Current Distribution in Parallel Circuits

The current flowing through each resistor R_i in the circuit is given by Ohm’s Law:

$$
I_i = \frac{V}{R_i}
$$

where V is the voltage across the resistor (which is the same for all in parallel). The total current supplied by the source, I_{total}, is the sum of the individual branch currents:

$$
I_{total} = \sum_{i} I_i
$$

This configuration allows us to analyze how changing one resistor affects the current distribution, especially when given specific conditions, such as one branch's current being a multiple of the total current.

Setting Up the Problem: The Conditions and Known Values

Suppose we have a parallel circuit powered by a voltage source V. The circuit has two resistors, R_1 and R_2. The question states:

- The current through R_2, denoted as I_{R_2}, is five times the total current I_{total}.

Mathematically:

$$
I_{R_2} = 5 \times I_{total}
$$

Given this relationship, our goal is to find the value of R_2 in ohms.

Deriving the Mathematical Relationships

Expressing Currents in Terms of Resistance and Voltage

Using Ohm’s Law:

$$
I_{R_2} = \frac{V}{R_2}
$$

Similarly, the total current is:

$$
I_{total} = I_{R_1} + I_{R_2} = \frac{V}{R_1} + \frac{V}{R_2}
$$

The key condition becomes:

$$
\frac{V}{R_2} = 5 \left(\frac{V}{R_1} + \frac{V}{R_2} \right)
$$

Dividing both sides by V (assuming $V \neq 0$):

$$
\frac{1}{R_2} = 5 \left(\frac{1}{R_1} + \frac{1}{R_2} \right)
$$

Solving for R_2: Step-by-Step Approach

The above equation simplifies to:

$$
\frac{1}{R_2} = \frac{5}{R_1} + \frac{5}{R_2}
$$

Bring all terms involving R_2 to one side:

$$
\frac{1}{R_2} - \frac{5}{R_2} = \frac{5}{R_1}
$$

Simplify the left side:

$$
-\frac{4}{R_2} = \frac{5}{R_1}
$$

Now, solve for R_2:

$$
R_2 = -\frac{4 R_1}{5}
$$

The negative sign indicates an inconsistency if taken at face value, as resistance cannot be negative. This suggests the need for a reconsideration of initial assumptions or an additional context, such as the value of R_1.

Note: Since resistance cannot be negative physically, the negative result indicates that for the initial assumption to hold, the given ratio must be interpreted differently or additional constraints are necessary.

Incorporating Practical Constraints and Additional Information

To resolve the negative resistance issue, consider the following practical scenario:

- The resistor R_1 is a known positive value.
- The condition $I_{R_2} = 5 \times I_{total}$ is maintained.
- The voltage source V is known or assumed.

Using the earlier relationship:

$$
I_{total} = I_{R_1} + I_{R_2}
$$

and

$$
I_{R_2} = 5 I_{total}
$$

which implies:

$$
I_{R_2} = 5 (I_{R_1} + I_{R_2})
$$

Rearranged:

$$
I_{R_2} = 5 I_{R_1} + 5 I_{R_2}
$$
$$
I_{R_2} - 5 I_{R_2} = 5 I_{R_1}
$$
$$
-4 I_{R_2} = 5 I_{R_1}
$$

Expressing in terms of resistances:

$$
I_{R_1} = \frac{V}{R_1}
$$
$$
I_{R_2} = \frac{V}{R_2}
$$

Substitute:

$$
-4 \times \frac{V}{R_2} = 5 \times \frac{V}{R_1}
$$

Dividing through by V:

$$
-\frac{4}{R_2} = \frac{5}{R_1}
$$

Again, the negative resistance indicates that the initial assumption leads to an unphysical solution unless the context involves other elements like negative resistances or active components, which are beyond passive circuit analysis.

Clarifying the Physical Interpretation and Practical Solution

Given the mathematical contradiction, the most plausible scenario is that the initial problem intended to express that the current through R_2 is five times the current through R_1 or the total current. Clarifying this distinction is crucial.

Suppose the problem is:

"In a parallel circuit, determine the value of R_2 such that the current through R_2 is five times the current through R_1."

This is a common problem in circuit analysis and leads to a straightforward solution.

Solving for R_2 When $I_{R_2} = 5 I_{R_1}$

Express the currents:

$$
I_{R_1} = \frac{V}{R_1}
$$

$$
I_{R_2} = \frac{V}{R_2}
$$

Set:

$$
\frac{V}{R_2} = 5 \times \frac{V}{R_1}
$$

Dividing both sides by V:

$$
\frac{1}{R_2} = \frac{5}{R_1}
$$

Rearranged:

$$
R_2 = \frac{R_1}{5}
$$

This implies that to have the current through R_2 be five times the current through R_1, the resistance R_2 must be one-fifth of R_1.

Practical Example and Numerical Calculation

Suppose $R_1 = 100\, \Omega$, then:

$$
R_2 = \frac{100\, \Omega}{5} = 20\, \Omega
$$

In this case:

- Voltage across each resistor is the same (say, $V = 10\, V$)
- Current through R_1:

$$
I_{R_1} = \frac{10\, V}{100\, \Omega} = 0.1\, A
$$

- Current through R_2:

$$
I_{R_2} = \frac{10\, V}{20\, \Omega} = 0.5\, A
$$

which satisfies the condition $I_{R_2} = 5 \times I_{R_1}$.

Extending to the Original Problem: Total Current Perspective

If the original problem indeed refers to the total current in the circuit, then the condition is:

$$
I_{R_2} = 5 \times I_{total}
$$

and since:

$$
I_{total} = I_{R_1} + I_{R_2}
$$

we substitute:

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