

A Circuit With A Voltage Of 120 Volts Across Five Resistors In Parallel (5, 14, 21, 25, And 100 Ohms)

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Understanding how electrical circuits work is fundamental to both electronics enthusiasts and professionals. Among various circuit configurations, parallel circuits are particularly significant due to their unique properties, such as constant voltage across components and the ability to operate independently. In this article, we delve into a specific scenario: a circuit with a voltage of 120 volts applied across five resistors in parallel with resistances of 5, 14, 21, 25, and 100 ohms. We will explore the electrical principles involved, perform detailed calculations, and discuss practical applications and safety considerations.

Introduction to Parallel Circuits

What Is a Parallel Circuit?

A parallel circuit is a configuration where multiple components are connected across the same voltage source. Each component forms its own branch, allowing current to split and flow through each resistor independently. This contrasts with series circuits, where components are connected end-to-end, sharing the same current but dividing the voltage.

Key Characteristics of Parallel Circuits

- Same Voltage Across All Components: All resistors in parallel experience the same voltage, which in this case is 120 volts.
- Total Current Is the Sum of Branch Currents: The overall current supplied by the source equals the sum of currents through each resistor.
- Equivalent Resistance Is Lower: Adding more resistors decreases the total resistance, improving current flow.

Calculating Total Resistance in a Parallel Circuit

Understanding the Formula

The total or equivalent resistance (R_{total}) in a parallel circuit with resistors R_1 , R_2 , R_3 , R_4 , and R_5 is given by:

$$\frac{1}{R_{\text{total}}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4} + \frac{1}{R_5}$$

This reciprocal sum ensures the total resistance accounts for the combined conductance of all branches.

Calculating R_{total}

Given resistances:

- $R_1 = 5 \, \Omega$
- $R_2 = 14 \, \Omega$
- $R_3 = 21 \, \Omega$
- $R_4 = 25 \, \Omega$
- $R_5 = 100 \, \Omega$

Calculations:

$$\frac{1}{R_{\text{total}}} = \frac{1}{5} + \frac{1}{14} + \frac{1}{21} + \frac{1}{25} + \frac{1}{100}$$

Breaking down each term:

- $\left(\frac{1}{5} = 0.2 \right)$
- $\left(\frac{1}{14} \approx 0.0714 \right)$
- $\left(\frac{1}{21} \approx 0.0476 \right)$
- $\left(\frac{1}{25} = 0.04 \right)$
- $\left(\frac{1}{100} = 0.01 \right)$

Sum:

$$0.2 + 0.0714 + 0.0476 + 0.04 + 0.01 = 0.369$$

Therefore:

$$R_{\text{total}} = \frac{1}{0.369} \approx 2.71, \text{ ohms}$$

\]

This low equivalent resistance indicates a high total current draw when connected to 120 volts.

Calculating Total Current Draw

Using Ohm's Law

Ohm's Law states:

\[

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

\]

Total current supplied by the source:

\[

$$I_{\text{total}} = \frac{V}{R_{\text{total}}} = \frac{120\text{V}}{2.71\,\Omega} \approx 44.28\text{A}$$

\]

This substantial current emphasizes the importance of proper circuit design and safety measures to prevent overheating or damage.

Branch Currents Calculation

Currents through individual resistors:

\[

$$I_n = \frac{V}{R_n}$$

\]

- Resistor 5 Ω :

\[

$$I_1 = \frac{120}{5} = 24\text{A}$$

\]

- Resistor 14 Ω :

\[

$$I_2 = \frac{120}{14} \approx 8.57\text{A}$$

\]

- Resistor 21 Ω :

\[

$$I_3 = \frac{120}{21} \approx 5.71\text{A}$$

\]

- Resistor 25 Ω :

\[

$$I_4 = \frac{120}{25} = 4.8\text{A}$$

\]
- Resistor 100 Ω :
\[
 $I_5 = \frac{120}{100} = 1.2$, \text{A}
\]

Summing these:

\[
 $24 + 8.57 + 5.71 + 4.8 + 1.2 \approx 44.28$, \text{A}
\]

which matches the total current calculated earlier, confirming the consistency of the calculations.

Power Dissipation in Each Resistor

Power Formula

The power dissipated by each resistor is given by:

\[
 $P = V \times I = I^2 \times R = \frac{V^2}{R}$
\]

Calculating power for each resistor:

- 5 Ω resistor:

\[
 $P_1 = \frac{120^2}{5} = \frac{14400}{5} = 2880$, \text{W}
\]

- 14 Ω resistor:

\[
 $P_2 = \frac{14400}{14} \approx 1028.57$, \text{W}
\]

- 21 Ω resistor:

\[
 $P_3 = \frac{14400}{21} \approx 685.71$, \text{W}
\]

- 25 Ω resistor:

\[
 $P_4 = \frac{14400}{25} = 576$, \text{W}
\]

- 100 Ω resistor:

\[
 $P_5 = \frac{14400}{100} = 144$, \text{W}
\]

Note: These power levels are significant, especially for the 5 Ω resistor, which dissipates 2880 watts. Such high power indicates the need for high-

wattage resistors and adequate cooling.

Practical Applications and Safety Considerations

Applications of Parallel Resistor Circuits

Parallel resistor circuits like this are common in various electrical and electronic applications, including:

- Power Distribution: Ensuring consistent voltage across multiple components.
- Load Balancing: Distributing current among several loads.
- Voltage Regulation: Maintaining stable voltage levels in complex systems.
- Testing and Experimentation: Studying circuit behaviors under different configurations.

Safety Aspects

Given the high currents and power dissipation:

- Use High-Wattage Components: Resistors must handle the power levels calculated.
- Proper Insulation and Wiring: To prevent shorts and electric shocks.
- Overcurrent Protection: Fuses or circuit breakers should be employed.
- Cooling Solutions: Heat sinks or fans may be necessary for high-power resistors.
- Voltage Ratings: Ensure all components are rated for 120 volts and above.

Conclusion

A circuit with a voltage of 120 volts across five resistors in parallel—specifically resistances of 5, 14, 21, 25, and 100 ohms—demonstrates fundamental electrical principles such as resistor combination, current division, and power dissipation. Calculations reveal a total equivalent resistance of approximately 2.71 ohms, a total current of around 44.28 amperes, and significant power dissipation across each resistor. Understanding these parameters is crucial for designing safe, efficient, and functional electrical systems. When working with high currents and power levels, proper safety measures and component ratings are essential to prevent hazards and ensure reliable operation.

By mastering the analysis of such parallel resistor circuits, engineers and

hobbyists can better design and troubleshoot complex electrical systems, ensuring performance and safety standards are met.

Frequently Asked Questions

What is the total current flowing through the circuit with a 120 V supply and five parallel resistors?

The total current can be found using Ohm's law by calculating the equivalent resistance and then dividing the voltage by this resistance. The equivalent resistance is approximately 4.22 ohms, so the total current is about 28.44 A.

How do you calculate the equivalent resistance of these five resistors in parallel?

The equivalent resistance R_{eq} is found using the formula: $1/R_{eq} = 1/5 + 1/14 + 1/21 + 1/25 + 1/100$. After calculating, $R_{eq} \approx 4.22$ ohms.

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

Since the resistors are in parallel, each resistor has the full supply voltage of 120 V across it.

How do you find the current flowing through each resistor?

Use Ohm's law for each resistor: $I = V / R$. For example, the current through the 5 ohm resistor is $120 \text{ V} / 5 \Omega = 24 \text{ A}$.

Which resistor carries the highest current in this circuit?

The resistor with the lowest resistance, which is 5 ohms, carries the highest current, approximately 24 A.

What is the power dissipated by the 100-ohm resistor?

Using $P = V^2 / R$, the power dissipated is $120^2 / 100 = 144 \text{ W}$.

If one resistor fails open, how does it affect the circuit's total current?

An open resistor removes its branch from the circuit, increasing the equivalent resistance and decreasing the total current supplied by the source.

Can the total power consumed in this circuit be calculated? If so, how?

Yes, the total power is the sum of the power dissipated by each resistor, calculated as $P = V I$ for each resistor, or directly as $P_{\text{total}} = V^2 / R_{\text{eq}}$, which is approximately $120^2 / 4.22 \approx 3404 \text{ W}$.

Additional Resources

A Circuit With A Voltage Of 120 Volts Across Five Resistors In Parallel (5, 14, 21, 25, And 100 Ohms)

Understanding the behavior of electrical circuits is fundamental in both theoretical physics and practical engineering. Among various configurations, parallel circuits are particularly significant due to their widespread application in household wiring, electronic devices, and power distribution systems. This article delves into a specific parallel circuit featuring five resistors with resistances of 5 Ω , 14 Ω , 21 Ω , 25 Ω , and 100 Ω , all subjected to a voltage supply of 120 V. We will explore the circuit's fundamental principles, analyze its electrical parameters, and interpret the implications of its design.

Introduction to Parallel Circuits

Definition and Basic Characteristics

A parallel circuit is an electrical configuration where multiple components are connected across the same voltage source, such that each component has its own direct path to the power supply. The key feature of parallel arrangements is that the voltage across each resistor remains constant, regardless of the individual resistances or current flowing through each branch. This contrasts with series circuits, where the same current passes through all components but voltages divide among them.

The defining characteristics of parallel circuits include:

- Equal voltage across all branches.
- Total current is the sum of currents through each branch.
- The total or equivalent resistance is less than the smallest individual resistance in the network.
- Each branch operates independently; failure of one resistor does not necessarily affect others.

Significance in Practical Applications

Parallel wiring ensures devices operate at consistent voltages, crucial in household electrical systems. For example, outlets in a home are wired in parallel so each device receives the full supply voltage (typically 120 V in North America). Engineers leverage parallel circuits to optimize current distribution, maintain voltage stability, and facilitate component replacement without disrupting entire systems.

Analyzing the Circuit Parameters

Given Data and Basic Assumptions

- Voltage supply (V) = 120 Volts
- Resistors in parallel: $R_1 = 5\ \Omega$, $R_2 = 14\ \Omega$, $R_3 = 21\ \Omega$, $R_4 = 25\ \Omega$, $R_5 = 100\ \Omega$

The goal is to determine key electrical parameters:

- Equivalent resistance (R_{eq})
- Total current supplied by the voltage source (I_{total})
- Individual currents through each resistor (I_1 to I_5)
- Power dissipated by each resistor

Calculating the Equivalent Resistance

In a parallel circuit, the equivalent resistance (R_{eq}) is given by:

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

Applying the values:

\[

$$\frac{1}{R_{eq}} = \frac{1}{5} + \frac{1}{14} + \frac{1}{21} + \frac{1}{25} + \frac{1}{100}$$

Calculating each term:

$$\begin{aligned} - \left(\frac{1}{5} = 0.2 \right) \\ - \left(\frac{1}{14} \approx 0.07143 \right) \\ - \left(\frac{1}{21} \approx 0.04762 \right) \\ - \left(\frac{1}{25} = 0.04 \right) \\ - \left(\frac{1}{100} = 0.01 \right) \end{aligned}$$

Summing:

$$0.2 + 0.07143 + 0.04762 + 0.04 + 0.01 = 0.36905$$

Therefore:

$$R_{eq} = \frac{1}{0.36905} \approx 2.71\,\Omega$$

This low equivalent resistance indicates that the overall circuit allows a significant total current flow, which is typical when multiple low-resistance paths are connected in parallel.

Determining Total Current (I_{total})

Using Ohm's Law:

$$I_{total} = \frac{V}{R_{eq}} = \frac{120\,V}{2.71\,\Omega} \approx 44.29\,A$$

This substantial current underscores the importance of appropriate circuit design and safety measures, especially considering the high current potential.

Calculating Currents Through Individual Resistors

Since all resistors are connected across the same voltage, their individual currents are:

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

\]

Applying this:

- \(\ I_1 = \frac{120}{5} = 24\,A \)
- \(\ I_2 = \frac{120}{14} \approx 8.57\,A \)
- \(\ I_3 = \frac{120}{21} \approx 5.71\,A \)
- \(\ I_4 = \frac{120}{25} = 4.8\,A \)
- \(\ I_5 = \frac{120}{100} = 1.2\,A \)

Summing:

\[
24 + 8.57 + 5.71 + 4.8 + 1.2 \approx 44.28\,A
\]

which aligns closely with the total current calculated earlier, confirming the consistency of the analysis.

Power Dissipation in Each Resistor

Power dissipated in a resistor is given by:

\[
P_i = V \times I_i = \frac{V^2}{R_i}
\]

Calculations:

- \(\ P_1 = \frac{120^2}{5} = \frac{14,400}{5} = 2,880\,W \)
- \(\ P_2 = \frac{14,400}{14} \approx 1,028.57\,W \)
- \(\ P_3 = \frac{14,400}{21} \approx 685.71\,W \)
- \(\ P_4 = \frac{14,400}{25} = 576\,W \)
- \(\ P_5 = \frac{14,400}{100} = 144\,W \)

Note: These power values are significant, indicating that resistors must be rated appropriately to handle such dissipation, especially in high-power applications.

Implications and Practical Considerations

Safety and Component Ratings

The high currents and power dissipations in this circuit highlight several safety concerns:

- Resistor Power Ratings: Resistors must be rated for the power they dissipate to prevent overheating and failure. For instance, a resistor dissipating nearly 3 kW (like R1) would require specialized high-power components with adequate heat sinking.
- Wire Gauge and Connectors: Conductors should be capable of handling the large currents (~44 A), necessitating thicker wiring and robust connectors to prevent thermal hazards.
- Circuit Protection Devices: Fuses or circuit breakers must be rated to interrupt such high currents safely.

Design Considerations and Applications

In real-world applications, such a circuit might be part of a test setup or a specialized industrial system rather than a typical household circuit. This analysis underscores the importance of:

- Selecting resistors with appropriate power ratings.
- Ensuring wiring standards are met.
- Considering the total current draw to prevent overloads.

Efficiency and Energy Consumption

The circuit's low equivalent resistance results in high current draw, leading to substantial energy consumption. Power efficiency considerations may prompt engineers to explore alternative configurations or components to minimize losses, especially in power-sensitive applications.

Conclusion: Insights and Broader Context

This detailed examination of a 120 V circuit with five resistors in parallel reveals the fundamental principles governing such arrangements, from calculating equivalent resistance to understanding current distribution and power dissipation. The analysis illustrates that even seemingly simple circuits can harbor complex considerations—particularly regarding safety, component specifications, and energy efficiency.

In broader engineering practice, parallel circuits form the backbone of electrical distribution systems, enabling reliable operation of multiple devices at a uniform voltage. However, the high currents involved necessitate meticulous design, rigorous safety standards, and appropriate component

selection.

Ultimately, this exploration emphasizes the importance of comprehensive circuit analysis in ensuring safe, efficient, and reliable electrical systems. Whether in residential wiring, industrial machinery, or electronic devices, understanding the nuances of parallel resistor networks remains a cornerstone of electrical engineering, bridging theoretical insights with practical applications.

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