2023

6. Series and Parallel Circuits

R2: SCRAPY Guide

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Table of Contents

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1 Introduction

Simple circuits (ones with only a few components) are usually fairly straightforward for beginners to understand. But things can get sticky when other components come to the party. Where's the current going? What's the voltage doing? Can this be simplified for easier understanding? Fear not, intrepid reader. Valuable information follows.

In this lesson, we'll first discuss the difference between series circuits and parallel circuits, using circuits containing the most basic of components (resistors and batteries) to show the difference between the two configurations. We'll then explore what happens in series and parallel circuits when you combine different types of components, such as capacitors and inductors.

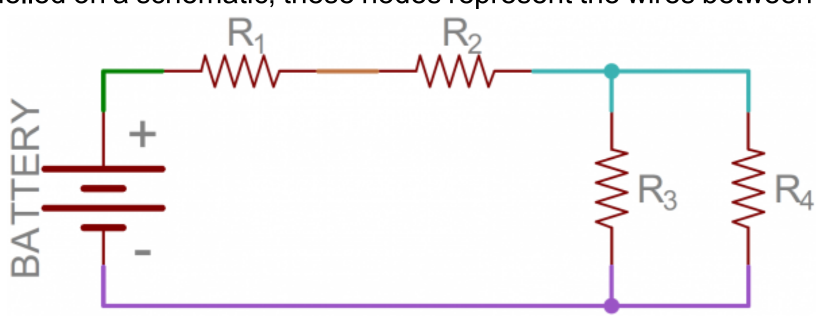
Covered in this Lesson

- What series and parallel circuit configurations look like
- How passive components act in these configurations
- How a voltage source will act upon passive components in this configuration

2 Series Circuits

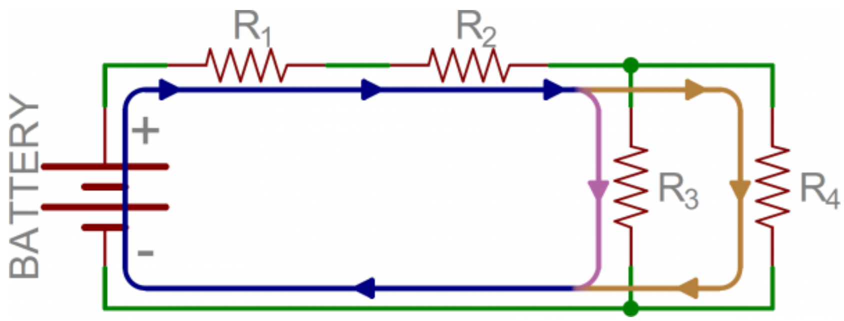
Nodes and Current Flow

Before we get too deep into this, we need to mention what a node is. It's nothing fancy, just a representation of an electrical junction between two or more components. When a circuit is modelled on a schematic, these nodes represent the wires between components.



Example schematic with four uniquely coloured nodes.

That's half the battle towards understanding the difference between series and parallel. We also need to understand how current flows through a circuit. Current flows from a high voltage to a lower voltage in a circuit. Some amount of current will flow through every path it can take to get to the point of lowest voltage (usually called ground). Using the above circuit as an example, here's how current would flow as it runs from the battery's positive terminal to the negative:

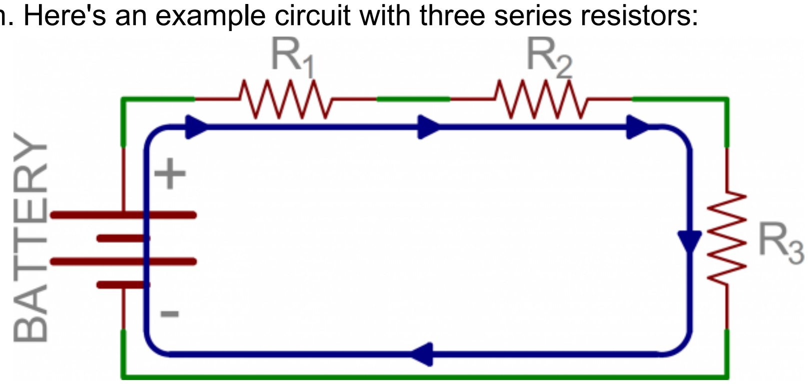


Current (indicated by the blue, orange, and pink lines) flowing through the same example circuit as above. Different currents are indicated by different colours.

Notice that in some nodes (like between R1 and R2) the current is the same going in as it is coming out. At other nodes (specifically the three-way junction between R2, R3, and R4) the main (blue) current splits into two different ones. That's the key difference between series and parallel!

2.1 Series Circuits Defined

Two components are in series if they share a common node and if the same current flows through them. Here's an example circuit with three series resistors:



Series Circuits Defined

There's only one way for the current to flow in the above circuit. Starting from the positive terminal of the battery, the current flow will first encounter R1. From there the current will flow straight to R2, then to R3, and finally back to the negative terminal of the battery. Note that there is only one path for the current to follow. These components are in series.

3. Parallel Circuits

Parallel Circuits Defined

If components share two common nodes, they are in parallel. Here's an example schematic of three resistors in parallel with a battery:

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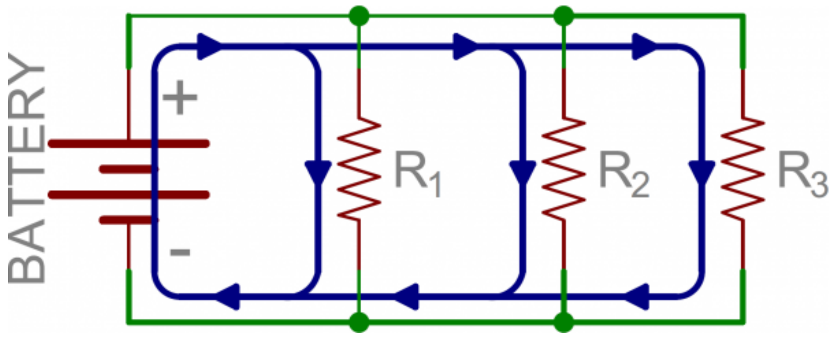


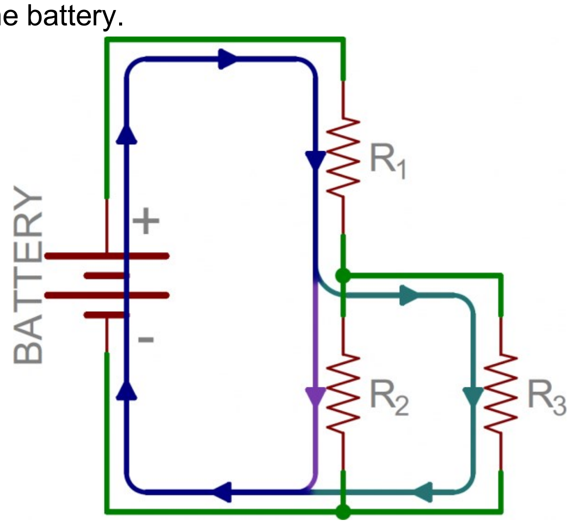
Parallel Circuits Defined

From the positive battery terminal, current flows to R1... and R2, and R3. The node that connects the battery to R1 is also connected to the other resistors. The other ends of these resistors are similarly tied together and then tied back to the negative terminal of the battery. There are three distinct paths that the current can take before returning to the battery, and the associated resistors are said to be in parallel.

Where series components all have equal currents running through them, parallel components all have the same voltage drop across them (series: current: parallel: voltage.

3.1 Series and Parallel Circuits Working Together

From there we can mix and match. In the next picture, we again see three resistors and a battery. From the positive battery terminal, the current first encounters R1. But, on the other side of R1, the node splits and the current can go to both R2 and R3. The current paths through R2 and R3 have then tied together again, and the current goes back to the negative terminal of the battery.



In this example, R2 and R3 are in parallel with each other, and R1 is in series with the parallel combination of R2 and R3.

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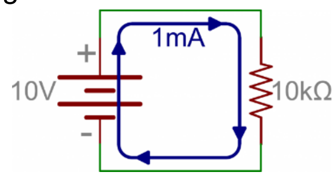
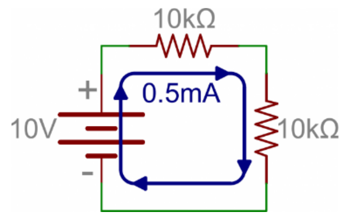
3.2 Calculating Equivalent Resistances in Series Circuits

Here's some information that may be of some more practical use to you. When we put resistors together like this, in series and parallel, we change the way current flows through them. For example, if we have a 10V supply across a 10kΩ resistor, **Ohm's law** says we've got 1mA of current flowing.



If we then put another 10kΩ resistor in series with the first and leave the supply unchanged, we've cut the current in half because the resistance is doubled.

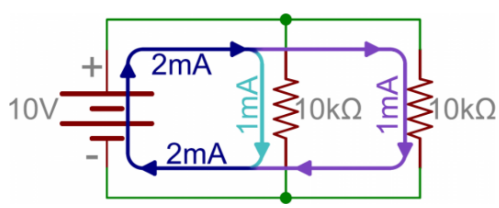


In other words, there's still only one path for the current to take and we just made it even harder for the current to flow. How much harder? 10kΩ + 10kΩ = 20kΩ. And that's how we calculate resistors in series, just add their values.

To put this equation more generally: the total resistance of N (some arbitrary number of) resistors is their total sum.

3.3 Calculating Equivalent Resistances in Parallel Circuits

What about parallel resistors? That's a bit more complicated, but not by much. Consider the last example where we started with a 10V supply and a 10kΩ resistor, but this time we add another 10kΩ in parallel instead of series. Now there are two paths for the current to take. Since the supply voltage didn't change, Ohm's Law says the first resistor is still going to draw 1mA. But so is the second resistor, and we now have a total of 2mA coming from the supply, doubling the original 1mA. This implies that we've cut the total resistance in half.



While we can say that 10kΩ || 10kΩ = 5kΩ ("||" translates to "in parallel with"), we're not always going to have 2 identical resistors. What then?

The equation for adding an arbitrary number of resistors in parallel is:

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$$\frac{1}{R_{tot}} = \frac{1}{R_1} + \frac{1}{R_2} + ... + \frac{1}{R_{N-1}} + \frac{1}{R_N}$$

If reciprocals aren't your thing, we can also use a method called “product over sum” when we have two resistors in parallel:

$$R_{tot} = \frac{R_1 \cdot R_2}{R_1 + R_2}$$

However, this method is only good for two resistors in one calculation. We can combine more than 2 resistors with this method by taking the result of R1 || R2 and calculating that value in parallel with a third resistor (again as a product over sum), but the reciprocal method may be less work.

4. Conclusion

Now that you're familiar with the basics of serial and parallel circuits, try to check out some of these lessons:

- Introduction to Sensors
- Analog vs. Digital
- Binary
- Digital Logic

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