

# Electrical Engineering

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## 3 Ohm's Law

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### 4.1 Parallel vs Series

## 5 Kirchhoff's Law

## 6 Alternative vs Direct Current

## 7 Passive components

We'll now take a detour from some of the more theoretical and physical laws to get a grasp of practical hands on concepts. This section will be focused on passive components, and the next will be focused on active components. Electronic components exist within every electronics device. Not all components can be classified as a load because not all components necessarily consume power, however, they do affect the behaviour of current, voltage, and resistance. Passive components are components which cannot control electric current utilizing a secondary electrical signal. Active components, on the other hand (which we'll look at in a bit) can control the current of the circuit. For example, a type of active component known as a transistor can amplify current using a secondary signal. We'll begin by looking at arguably the most basic type of passive component: the resistor.

### 7.1 Resistors

A resistor is perhaps one of the most common and simple components that makeup a circuit. Resistors add resistance to the circuit, thus inversely reducing current. Resistors are typically placed in series next to a load to reduce current draw. Resistors come in various shapes and sizes, as well as ratings. Since resistors deal with resistance, they are measured in Ohms. The schematic symbol for a resistor can resemble either of the symbols below.



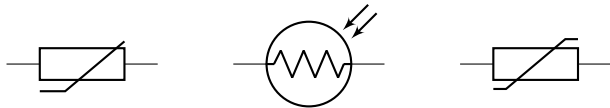
Resistors are not polarized, meaning that they don't have a particular polarity as to how you orient them (no positive/anode or negative/cathode leads). The style depicted on the left is more common in North America, whereas you may see the style on the right used more in Europe.

Most resistors are fixed, meaning that they have a resistance rating in Ohms which is the resistance that they'll stay at. Variable resistors, however, allow for tuning of the resistance between some range. A potentiometer is a device with three leads, typically used for knobs and dials, which tunes the resistance value and is usually intended to be operated by human intervention. A trim pot, on the other hand, is a similar device, but one which is typically meant to be tuned once in the factory and then left untouched. The schematic symbol for a variable resistor can appear as either the left or middle symbols and the right-hand symbol represents the symbol for a trim pot.



The left-hand symbol with the arrow pointing down is sometimes called a tap, which represents the position of the physical slide that affects its resistance value. Note that we could have used the European symbol for the resistor rather than the North American symbol for either of these, as well as the ones I'll show in the future, but I will be sticking with the North American version for future reference.

Some more types of variable resistor which are a bit more niche, but still used in certain applications include the thermistor, which is a resistor that changes resistance with temperature; photoresistor, which is photo-sensitive and fluxuates with light; as well as the varistor, which changes resistance according to voltage. To give some examples of where these are used: thermistors are used in 3D printers to sense the temperature of the hotend and varistors are used for surge protection, typically in conjunction with a fuse to mitigate the damage done to a circuit when high levels of voltage are applied. From left to right, I've laid out the thermistor, photoresistor, and varistor schematic symbols for you.

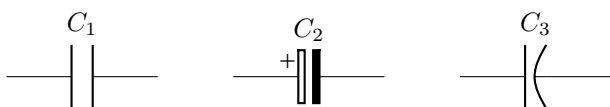


To provide some more nuance, the schematic symbol I've actually used for the varistor is the symbol for a metal-oxide varistor A.K.A. a MOV, which is likely the most common type you'll see. Another thing to note is that thermistors come in two forms: Positive Temperature Coefficient (PTC) and Negative Temperature Coefficient (NTC). PTC means that resistance increases as temperature increases, and vice versa for NTC. Also note the two diagonal arrows pointing towards the photoresistor. These represent photons or light, and can be used for other components to signify that the component is photosensitive. Arrows pointing the opposite direction indicate that the component is light-emitting, which we'll come to see with LEDs.

## 7.2 Capacitors

Similar to resistors, capacitors are another simple, yet crucial and commonly used component within electronic circuits. A capacitor, as the name suggests, has some capacitance for current, which builds incrementally before eventually discharging. Capacitors are typically used to dampen or smooth electrical impedance or sudden spikes in current due to various factors. They are also commonly used in timer circuits or placed in series with switches to reduce the risk of what's known as bouncing, whereby a switch or button registers multiple inputs even though the operator only intended to input one press.

To get a bit more technical, capacitors are made up of two metal plates which sandwich the dielectric. The dielectric is a material or fluid which stores the energy between the voltage differential. The dielectric is typically either a fluid containing electrolyte, which is where we get the term electrolytic capacitors, or it will be ceramic, hence the term ceramic capacitors. These two have pros and cons which I won't get into such as size, heat tolerance, etc. The primary difference, however, is that electrolytic capacitors have a polarity, whereas ceramic capacitors do not. Sometimes we refer to non-polarized capacitors as "fixed" capacitors. Similar to resistors, we can also have variable capacitors which can alter their capacitance. Below you'll see the symbols for fixed (left) and polarized capacitors (middle and right).

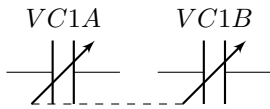


There exist other variations for electrolytic capacitors as well, though they are all fairly similar to the ones depicted above. A variable resistor, as well as any component with a variable quantity will use the same arrow that we used for variable resistors, and likewise for the trimmer capacitor, which are both depicted

below.



Note that for several variable components, we sometimes see them being "ganged" A.K.A. "linked", meaning that the changes applied to one component will cause the same effect to occur in the other. We denote that two variable components are ganged together using a dashed line to connect the bottom of the arrow as illustrated below for the two ganged variable capacitors.



**7.3 Inductors**

**7.4 Transformers**

## **8 Active Components**

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