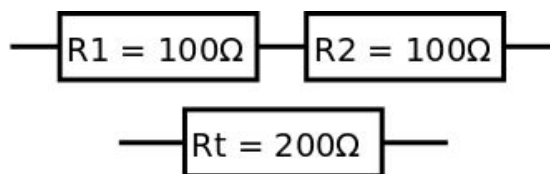


# Resistors in Series and Parallel

## Introduction

When two (or more) resistors are connected in series or in parallel, they are equivalent to just a single resistor but of a different value.

## Resistors in Series



Connecting two 100Ω resistors in series in a circuit has the same effect as using a single 200Ω resistor.

The two 100Ω resistors can be replaced by a single 200Ω resistor.

Or a single 200Ω resistor can be replaced by two 100Ω resistors in series - they are completely equivalent. The general principle is:

For resistors in series, the total resistance is greater than any of the individual resistances. For two resistors  $R_1$  and  $R_2$  having an equivalent resistance  $R_t$ ,  $R_t > R_1$  and  $R_t > R_2$ .

Mathematically, the resistor combination rule for two resistors is very straight forward:

$$R_t = R_1 + R_2$$

And for more than two resistors, the combination rule is simply:

$$R_t = R_1 + R_2 + R_3 + \dots$$

The special case of two equal value resistors is worth remembering: For two resistors, each of value  $R$ , in series the total resistance is  $2R$ .

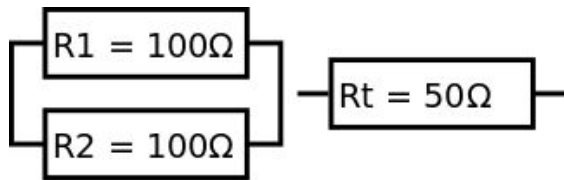
## Examples:

$$100\Omega \text{ in series with } 220\Omega = 320\Omega$$

$$1\text{ k}\Omega \text{ in series with } 100\Omega = 1100\Omega = 1\text{ k}1\Omega$$

$$50\Omega \text{ in series with } 50\Omega = 100\Omega$$

## Resistors in parallel



Connecting two 100Ω resistors in parallel in a circuit has the same effect as using a single 50Ω resistor.

The two 100Ω resistors in parallel can be replaced by a single 50Ω resistor or a single 50Ω resistor can be replaced by two 100Ω resistors in parallel - once again they are completely equivalent.

The general principle is: For resistors in parallel, the total resistance is smaller than any of the individual resistances. For two resistors R1 and R2 having an equivalent resistance Rt,  $R_t < R_1$  and  $R_t < R_2$ .

Mathematically, the resistor combination rules for resistors in parallel are slightly more complex and must be used with care.

For two resistors in parallel:

$$1/R_t = 1/R_1 + 1/R_2$$

or, alternatively:

$$R_t = (R_1 \times R_2)/(R_1 + R_2)$$

For more than two resistors in parallel:

$$1/R_t = 1/R_1 + 1/R_2 + 1/R_3 + \dots$$

The special case of two equal value resistors is again worth remembering: For two resistors, each of value R, in parallel the total resistance is  $\frac{1}{2}R$ .

### Examples:

100Ω in parallel with 220Ω = 69Ω

1 kΩ in parallel with 100Ω = 91Ω

50Ω in parallel with 50Ω = 25Ω

## Combining Resistors

A good question is "why do you need to combine resistors? Why not just use the desired value in the first place?". The answer is because (a) you want a non-standard value or (b) you need more power handling capability.

Resistors come in standard values, the most common set of resistor values is the E24 series. In this series of resistors, the standard values are: 10, 11, 12, 13, 15, 16, 18, 20, 22, 24, 27, 30, 33, 36, 39, 43, 47, 51, 56, 62, 68, 75, 82, 91 and the corresponding powers of 10 for each of these values.

## Getting the non-standard values:

If you need a value of  $190\ \Omega$  it isn't available in the E24 series - the nearest values are either  $180\ \Omega$  or  $200\ \Omega$ . Therefore a  $100\ \Omega$  and a  $91\ \Omega$  resistor can be used in series to give a value of  $191\ \Omega$  - which is close enough given a  $\pm 5\%$  uncertainty.

If you need a  $310\ \Omega$  resistor, connect two  $620\ \Omega$  resistors in parallel ... or a  $200\ \Omega$  and a  $110\ \Omega$  resistor in series ... there is always more than one way to make a resistor of the desired value.

To make a  $26\ \text{k}\Omega$  resistor use a  $10\ \text{k}\Omega$  resistor in series with a  $16\ \text{k}\Omega$  resistor OR use a  $24\ \text{k}\Omega$  in series with a  $2\ \text{k}\Omega$  ... and so it goes on.

Note: Remember resistors have a tolerance so there is no validity in combining lots of resistors to get an "exact" value. Assuming our resistors have a 5% tolerance, there is no point in combining a  $1\ \text{k}\Omega$  resistor and a  $33\ \Omega$  resistor in series hoping to make a  $1033\ \Omega$  resistor, the 5% tolerance on the  $1\ \text{k}\Omega$  resistor is already  $+ 50\ \Omega$ , an uncertainty bigger than the  $33\ \Omega$  that was added! Think about what you are doing before you start adding loads of smaller and smaller resistors in series.

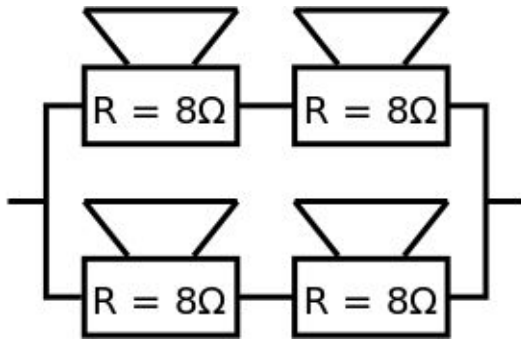
## Increasing the power handling:

Resistors all have a maximum power rating. If you have a pile of resistors all rated at  $1\ \text{W}$  maximum power rating then, combining two or more of these in series or parallel will result in an equivalent resistor with a higher power rating - the power is shared between the resistors that have been combined.

Combining two such  $10\ \Omega$   $1\ \text{W}$  resistors in parallel will be equivalent to a  $5\ \Omega$  resistor with a power rating of  $2\ \text{W}$ . The situation is only slightly more complex if the resistors don't have the same value, for example, a  $10\ \Omega$  resistor in series with a  $22\ \Omega$  resistor produces a  $32\ \Omega$  resistor with a power rating greater than  $1\ \text{W}$ .

A special case worth mentioning is when dealing with loudspeakers (thinking of loudspeakers as essentially the same as resistors).

Loudspeakers nominally have a resistance of  $8\ \Omega$  and can handle a certain power. To ensure the audio system works most efficiently, loudspeakers must always have a resistance of  $8\ \Omega$ . Therefore, to increase the power handling, we need to combine the loudspeakers in both series and parallel to produce an arrangement that still has a resistance of  $8\ \Omega$  but a greater power handling.

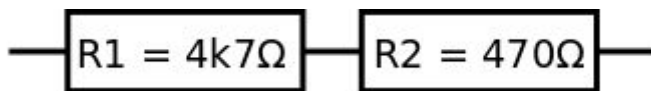


The diagram shows how this is accomplished. The two  $8\Omega$  speakers in series add up to  $16\Omega$ . The two  $16\Omega$  pairs in parallel make  $8\Omega$  in total.

A notable exception is in the case of P.A. system speakers that often have a resistance of only  $4\Omega$  and speakers used in car audio systems where the speaker resistance can be even lower.

## Examples

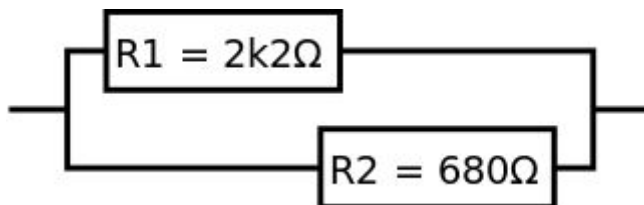
Example 1:



Two resistors in series are easy to add up but, in this example, it is important to make sure the units are correct:  $4k7\Omega = 4700\Omega$

$$R_t = 4700 + 470 = 5170\Omega$$

Example 2:



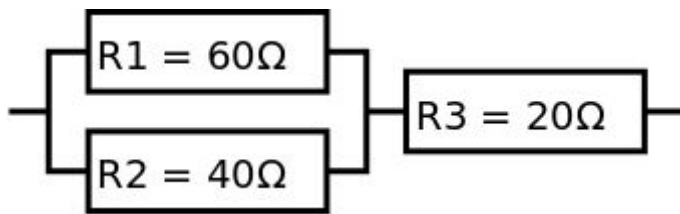
As in the first example, ensure the units are correct.

$$1/R_t = 1/2200 + 1/680$$

and therefore

$$R_t = 519\Omega$$

### Example 3:



This example has to be considered in two parts as there are both parallel and series resistors. First R1 and R2 need to be added in parallel. Then, the series resistor R3 is added to give the total resistance of the three resistors.

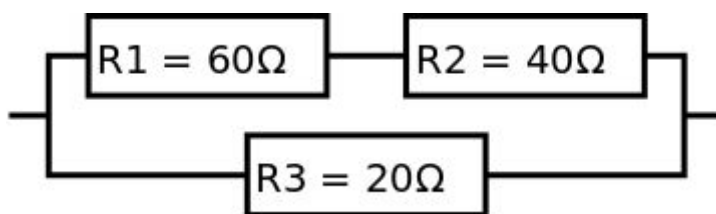
Considering the parallel pair of R1 and R2 (and using the alternative form of the parallel resistor equation)

$$R_t = (60 \times 40) / (60 + 40) = 24\Omega$$

Adding R3 in series gives

$$R_t = 24 + 20 = 44\Omega$$

### Example 4:



In this example there are also series and parallel resistors combined. In this case the series resistors R1 and R2 must be combined first. The result is then combined in parallel with R3.

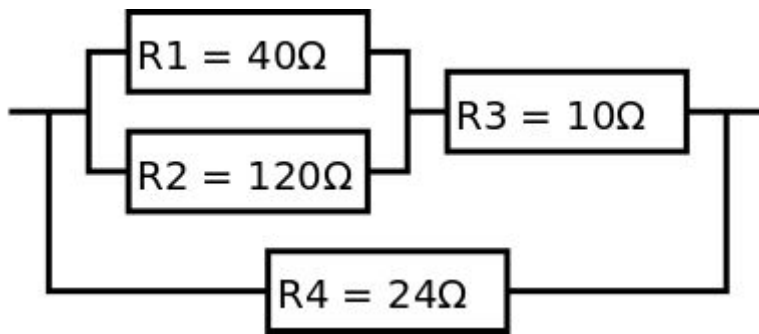
Considering the series pair R1 and R2

$$R_t = 60 + 40 = 100\Omega$$

Adding R3 in parallel gives

$$R_t = (100 \times 20) / (100 + 20) = 16.7\Omega = 17\Omega$$

## Example 5:



In this more complex example the resistors must once again be combined in pairs in the correct order. First R1 and R2 are added in parallel. Next the series resistor R3 is added to the previous result. Finally the total of R1, R2 and R3 is added in parallel to R4 ... simple!

Considering R1 and R2 in parallel

$$R_t = (40 \times 120) / (40 + 120) = 30\Omega$$

Adding R3 gives

$$R_t = 30 + 10 = 40\Omega$$

Finally, adding R4 in parallel with the 40Ω combination gives

$$R_t = (40 \times 24) / (40 + 24) = 15\Omega$$

## Website

[http://www.pfnicholls.com/Electronics/series\\_parallel.html](http://www.pfnicholls.com/Electronics/series_parallel.html)

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