Online Radio & Electronics Course

Reading 5

Ron Bertrand VK2DQ
http://www.radioelectronicschool.com

SERIES CIRCUITS

When components in a circuit are connected in successive order with the end of each joined up to the other end of the next as shown below in figure 1, they form a series circuit.
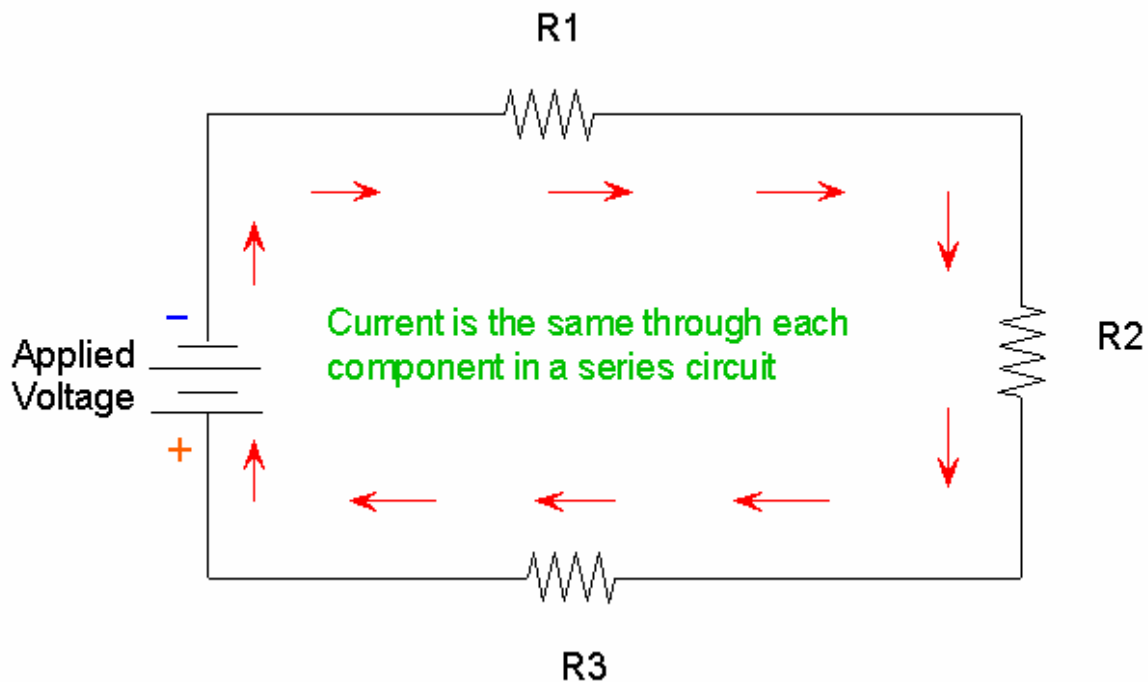

Figure 1.

An electric current consists of an ordered movement of electrons. In the schematic shown in figure 1, the current leaves the negative terminal of the battery and flows through R_1, R_2 and R_3.

It does not matter where we measure the current in a series circuit as we will always get the same value of current everywhere, as:

Current is the same in all parts of a series circuit.

The total resistance of any number of resistances in series is simply the sum of the individual resistances:

$$R_t = R_1 + R_2 + R_3.. \text{ etc}$$

Suppose the resistors in figure 1 were 10, 20 and 30 ohms respectively and the applied voltage was 10 volts. What is the current flowing in the circuit?

$$R_t = R_1 + R_2 + R_3$$

1

$R_t = 10 + 20 + 30$
$R_t = 60$ ohms.

We now know the total resistance (60 ohms), and the applied voltage is 10 volts, so we can use ohm's law to calculate the current flowing in the circuit.

$I = E/R$ = 10/60 = 1/6 A or 0.1666 A or 166.6 milliamps

All of the resistances shown in the five circuits of figure 2, are in series. The circuits are drawn differently, but nevertheless they are all series circuits and the current is the same in every part of the circuit. The rectangle symbol is an alternative method of drawing a resistor.
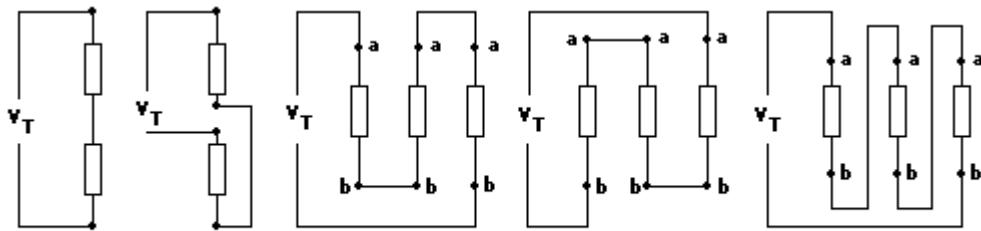
Converted to electronic format by Daniel Bartlett. http://www.dcac.cjb.net

Figure 2.

Another rule that you must learn is:

The sum of the voltage drops in a series circuit is equal to the applied voltage.

Going back to figure 1, we have three resistances R_1, R_2 and R_3 in series, connected to a 10 volt supply. We can calculate the voltage across R_1 because we know the resistance and we know the current through R_1. Let's call the voltage across R_1 'E_{R1}', then:

$E_{R1} = I \times R_1 = 0.1666 \times 10 = 1.666$ volts

And for the other two resistances:

$E_{R2} = I \times R_2 = 0.1666 \times 20 = 3.332$ volts

$E_{R3} = I \times R_3 = 0.1666 \times 30 = 4.998$ volts

The sum of the voltage drops across each resistance will equal the applied voltage. There will be a small error in our example due to rounding of decimals.

$E_t = E_{R1} + E_{R2} + E_{R3} = 1.666 + 3.332 + 4.998 = 9.996$ volts (with rounding error).

Notice how the supply voltage is distributed around the circuit - think about it for a while. The least resistance has the smallest voltage drop across it and the largest resistance has the most voltage across it. This makes sense when we realise that the current in a series circuit must be the same through all components. R_3 needs nearly half of the supply voltage to get 0.1666 amps to flow through it and R_1 requires only 1.666 volts to produce the same current through it.

If two resistances of equal value were connected in series across a supply voltage of say 20 volts, then each resistance would have exactly half the supply voltage across it.

You can work out the voltage drops in a series circuit by using a method know as proportion.

Lets use our series circuit again and this time we will work out the voltage drops for R_1, R_2 and R_3 without using the current.

The total resistance of the circuit is 60 ohms (R_t) and the supply voltage is 10 volts.

E_{R1} = R_1/R_t x 10 = 10/60 x 10 = 1.6667 volts (rounded)
E_{R2} = R_2/R_t x 10 = 20/60 x 10 = 3.3334 volts (rounded)
E_{R3} = R_3/R_t x 10 = 30/60 x 10 = 5 volts

AN EXAMPLE OF A SERIES CIRCUIT

The best example I can think of for a common series circuit which will also demonstrate one of the problems with series circuits is Christmas tree lights. These lights are low voltage lights operating usually on 10 volts. However Christmas tree lights plug into the mains voltage of 240 volts. However if each bulb requires 10 volts and you connect 24 of them in series then each bulb will have 10 volts across it.

At least this is the way Christmas tree lights are supposes to work. Darn dangerous things if you ask me, as if you break a bulb you are exposing yourself to potentially (no pun intended) 240 volts.

So, from the point of view of Christmas tree lights, series circuits have an advantage. The disadvantage is, should a bulb blow, no current will flow in the circuit and all the lights will go out.

What would happen if you placed a short circuit where a bulb had blown (don't do this by the way)? The remaining 23 lights would come on again as you have completed the circuit, however they would all be a little brighter than intended as they will now have a little more than their designated 10 volts each. Of course running them at a higher voltage will cause them to burn out faster, so if you continued down this track and survived, you would find that the bulbs would blow faster and faster until eventually they would blow immediately.

POWER IN A SERIES CIRCUIT

The total power in a series circuit is found by P=EI where E is the applied voltage and I is the total current.

In our example: 10 x 0.1666 = 1.666 watts

You can use any of the power equations to calculate the power dissipated in R_1, R_2 or R_3. Of course the sum of the power dissipated in each resistance should equal the total power in the circuit (1.666 watts).

P_{R1} = I^2 x R_1 = $(0.1666)^2$ x 10 = 0.2775556 watts

And so on for each of the other resistors. However when you are done, the power dissipated in each resistor should add up to the total power dissipated in the circuit.

$$P_t = P_{R1} + P_{R2} + P_{R3}$$

Series resistive circuits are commonly used in electronics and communications, usually in very low power circuits.

THE VOLTAGE DIVIDER

The most common example I can think of is where a component in a circuit requires a voltage across it which is less than the supply voltage. Two resistors can be connected to produce a voltage divider.

Suppose we have a mystery component that requires 2 volts across it to work, and our supply voltage is 9 volts.
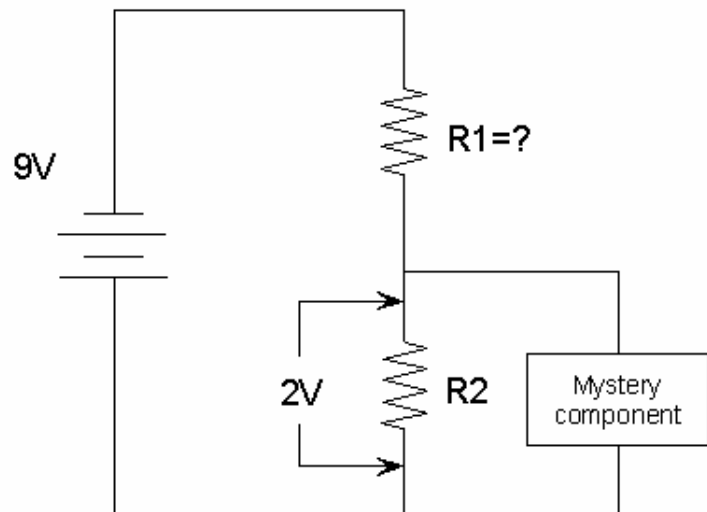
Such a circuit is shown in figure 3.

Figure 3.

Since we have not looked at parallel circuits yet, we will assume that the total resistance of the mystery component is 8000 ohms and this is represented by the resistance R_2.

Our problem then is to find the value of R_1.

We know that the sum of the voltage drops across R_1 and R_2 must equal the supply voltage of 9 volts. R_2 has 2 volts across it so R_1 must have 7 volts across it.

It should be obvious that the resistance value of R_1 must be higher than that of R_2 since it has the higher voltage across it.

Let's try this:

E_{R2} we know is 2 volts and R_2 is 8000 Ω.

We can calculate the current through R_2:

$$I_{R2} = E_{R2}/R_2 = 2/8000 = 0.25 \text{ milliamps}$$

We now know the current through R_1 since R_2 and R_1 are in series.

$$R_2 = E_{R2}/I_{R2}$$

In case the abbreviations are confusing you - E_{R2} means the voltage across R_2 and I_{R2} means the current through R_2.

    R_1= 7 volts / 0.25 milliamps ← remember this is milliamps
    R_1 = 28000 Ω

We can check this by saying:

    8000/36000 'th of the supply voltage should be across R_2,
    or 8/36 x 9 which gives 2 volts - correct.
Also:
    28000/36000 'th of the supply voltage should be across R_1,
    28/36 x 9 = 7 volts.

Note: Do you have problems using a calculator? Check the downloads section on the web site for a calculator tutorial. You may find many other useful tools and tutorials in the supplementary downloads section to help you as you proceed through this course.

End of Reading 5.
Last revision: November 2001
Copyright © 1999-2001 Ron Bertrand
E-mail: manager@radioelectronicschool.com
http://www.radioelectronicschool.com
Free for non-commercial use with permission