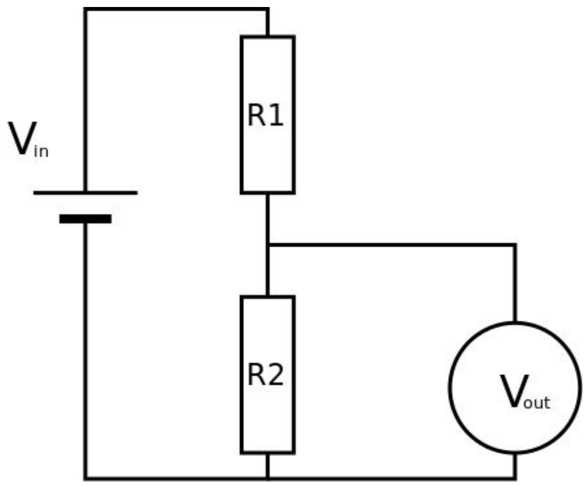
Potential Dividers

Introduction

Potential dividers are a very common part of even the most complex circuits and it is therefore very important to understand what they do and how to do the associated calculations.

A **potential divider** circuit is also known as a **voltage divider** circuit.

Basic Concepts



A potential divider is a pair of resistors connected in series and connected to a power supply or other source of EMF (voltage).

The potential difference across ONE of the resistors is a fraction of the applied EMF. The total potential difference across the resistors is divided between the two resistors, each having its own potential difference - hence potential divider.

In essence, a potential divider is a circuit with an input and an output. You apply a voltage to the input (V_{in}) and get a smaller voltage at the output (V_{out}). The output voltage is a fraction of the input voltage.

The output voltage depends on (a) the input voltage and (b) the ratio of the two resistors.

Note: The output voltage **does not** depend on the actual value of the individual resistors, it depends on the ratio of the pair of resistors - they work together and the output of the potential divider depends on their relative values.

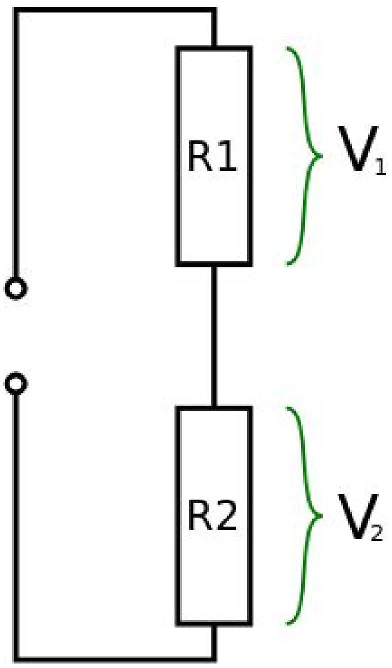
Potential Divider Equation

The output voltage from a potential divider (V_{out}) is given by the potential divider equation:

$$V_{out} = V_{in} \times R2 / (R1 + R2)$$

It is important to be able to use this equation.

Method of Ratios



The potential divider equation is very useful for calculating V_{out} but it is less obvious when trying to calculate R1 or R2.

It is usually much easier to use the ratios of the voltages to work out what resistor values to use. The ratio of the voltages is equal to the ratio of the resistances:

$$V1 \div V2 = R1 \div R2$$

or

$$V1 : V2 = R1 : R2$$

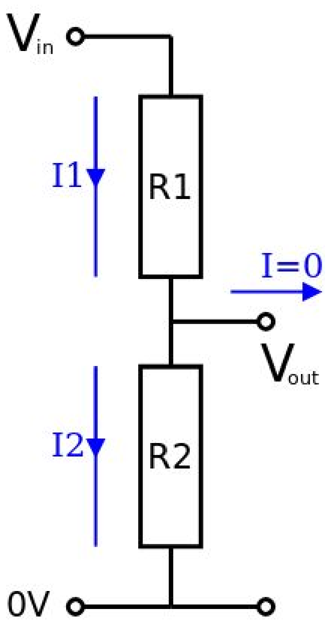
or

$$V1 : V_{out} = R1 : R2$$

Knowing V_{in} and V_{out} means you know V1 and V2 (V2 is V_{out} of course).

Once you know V1 and V2 you can choose R1 and R2 accordingly

An Important Consideration



The potential divider equation relies on the fact that the current in R1 is the same as the current in R2 and no current flows in the load (the load has an infinite resistance).

If this is NOT the case, the potential divider equation will not give a correct value for V_{out} and neither will the method of using ratios.

When calculating values of V_{out}, R1 or R2 it is always assumed that **no current flows** from the output of the potential divider

In reality, this is not possible to achieve. Any load such as a voltmeter or subsystem connected to the output of the potential divider will always take some current.

However, the theory is very nearly correct when the current flowing from the potential divider to the load is much less than the current through R1 and R2.

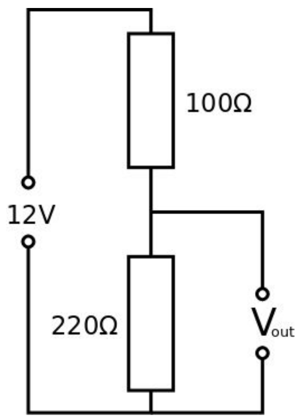
In practice, the values of R1 and R2 should be several orders of magnitude smaller than the resistance of the load.

For example, if a voltmeter has a resistance of 1 MΩ then a potential divider made from a pair of 10 kΩ resistors will work as expected but a potential divider made from a pair of 500 kΩ resistors will give a value of V_{out} smaller than expected.

The finite resistance of the load is effectively in parallel with R2 which reduces the overall combined resistance of R2 and therefore reduces V_{out}.

Examples

Example 1



Given the two resistor values and the supply voltage, find the output voltage.

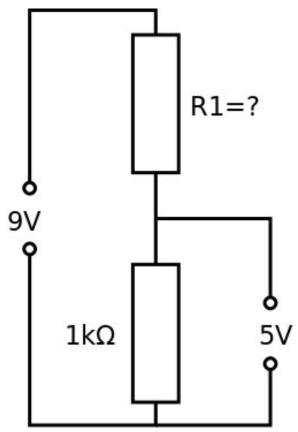
The values given are non trivial so the best approach is to use the equation for V_{out}

$$V_{out} = 12 \times 220 / (100 + 220)$$

Therefore:

V_{out} = 8.25 Volts

Example 2



Given V_{out} = 5 V, V_{in} = 9 V and R2 = 1 kΩ calculate R1.

The best approach when trying to find a resistor value is to use the method of ratios.

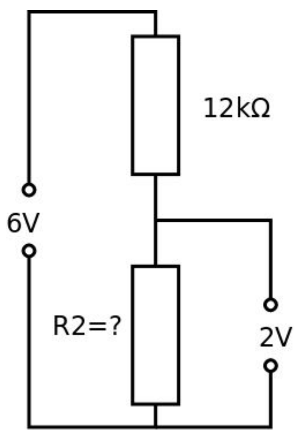
The voltage across R2 is 5 V and therefore the voltage across R1 is 4 V

$$4 : 5 = R1 : 1000$$

Therefore:

R1 = 800 Ω

Example 3



Given V_{out} = 2 V, V_{in} = 6 V and R1 = 12 kΩ calculate R2.

Again, the best approach when trying to find a resistor value is to use the method of ratios.

Voltage across R2 is 2 V therefore the voltage across R1 is 4 V

$$4 : 2 = 12k : R2$$

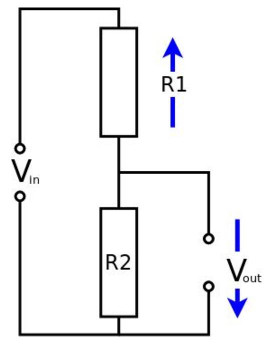
Therefore:

R2 = 6 kΩ

Effect of Changing R1 and R2

Where one of the resistors in a potential divider is variable - an LDR or Thermistor for example - it is very important to know how V_{out} changes when either R1 or R2 changes (and V_{in} remains fixed).

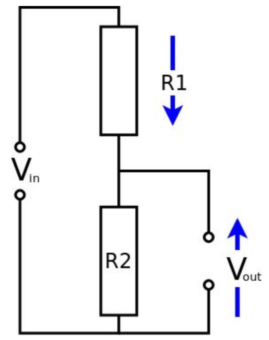
Case 1: R1 increases



R1 increases and takes a larger share of the input voltage

Therefore, the remaining voltage, V_{out} goes down

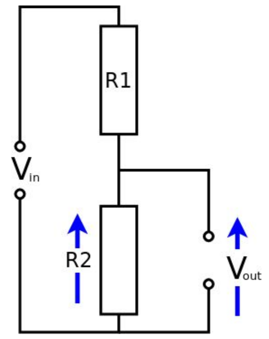
Case 2: R1 decreases



R1 decreases and takes a smaller share of the input voltage

Therefore, V_{out} goes up

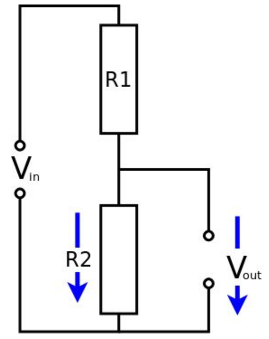
Case 3: R2 increases



R2 increases and takes a larger share of the input voltage

Therefore, V_{out} goes up

Case 4: R2 decreases



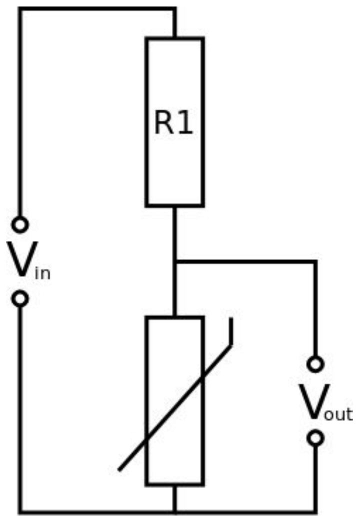
R2 decreases and takes a smaller share of the input voltage

Therefore, V_{out} goes down

Potential Dividers with LDRs and Thermistors

Consider (and learn and understand) each of the following examples:

Thermistor as R2:



As the temperature increases the resistance of the thermistor decreases.

As the resistance decreases, V_{out} decreases.

Therefore, V_{out} goes down as the temperature increases.

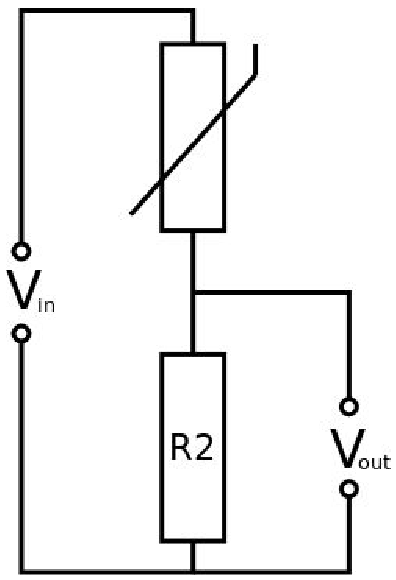
As the temperature decreases the resistance of the thermistor increases.

As the resistance increases, V_{out} increases.

Therefore, V_{out} goes up as the temperature decreases

A similar situation occurs if an LDR is used in place of R2. If the light level increases, V_{out} goes down and vice versa

Thermistor as R1



As the temperature increases the resistance of the thermistor decreases.

As the resistance decreases, V_{out} increases.

Therefore, V_{out} goes up as the temperature increases

As the temperature decreases the resistance of the thermistor increases.

As the resistance increases, V_{out} decreases.

Therefore, V_{out} goes down as the temperature decreases

A similar situation occurs if an LDR is used in place of R1. If the light level increases, V_{out} goes up and vice versa

Website

https://www.electronicsteaching.com/Electronics_Resources/DocumentIndex.html

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