Electronics
Resistive Sensors and Bridge Circuits

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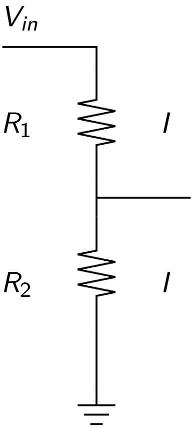
September 27, 2012

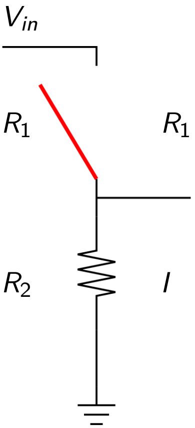
Switches in voltage dividers

- One of the simplest forms of voltage divider is where one of the elements is a *switch*.
- A switch can be thought of as a resistor which can have a value of either zero or infinity.
- Following is an illustration of a voltage divider where one element is a switch.



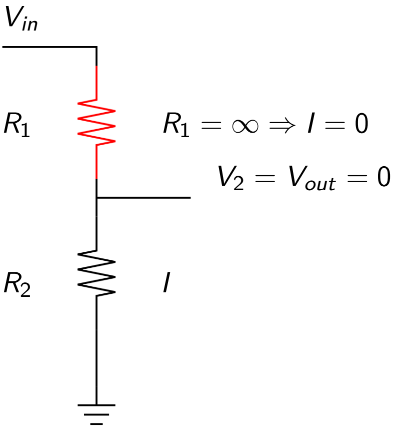
$$V_{out} = V_{in}\left(\frac{R_2}{R_1+R_2}\right)$$

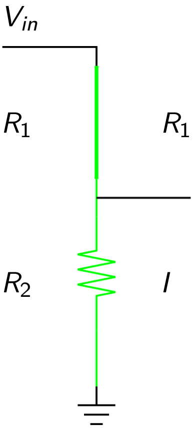
True if $I_{out} \equiv 0$



$$R_1 = \infty \Rightarrow I = 0$$

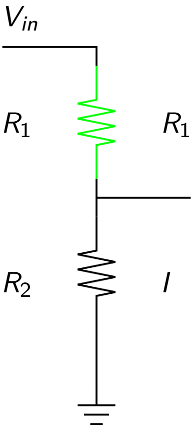
$$V_2 = V_{out} = 0$$


V_{in}
R_1
$R_1 = \infty \Rightarrow I = 0$
$V_2 = V_{out} = 0$
R_2
I



$R_1 = 0 \Rightarrow V_1 = 0$

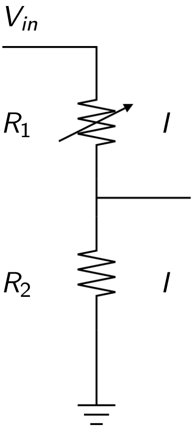
$V_2 = V_{out} = V_{in}$



$R_1 = 0 \Rightarrow V_1 = 0$

$V_2 = V_{out} = V_{in}$

- So if one of the elements is a *switch*, the output varies between 0 and V_{in}.
- If either resistor in a voltage divider is *variable*, then a range of output voltages is possible.



$$V_{out} = V_{in}\left(\frac{R_2}{R_1+R_2}\right)$$

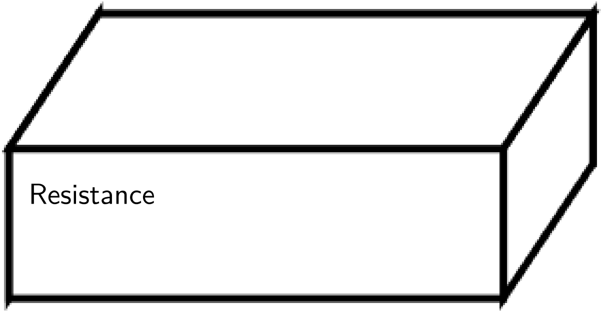
True if $I_{out} \equiv 0$

Resistive sensors

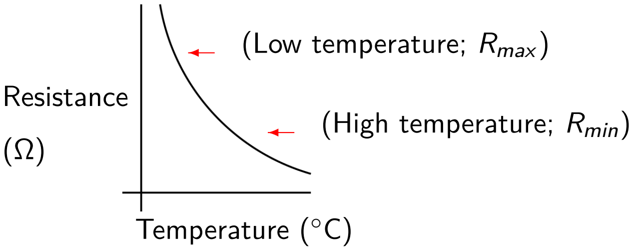
A **resistive sensor** is a resistor which changes according to some physical change in its environment. Some examples would be:

- Potentiometer; the resistance varies with *physical movement*
- Photoresistor; the resistance varies with *light*
- Thermistor; the resistance varies with *heat*
- Strain gauge (or gage); the resistance varies with *stress* or *compression*
- Force-dependent resistor; the resistance varies with *applied pressure*

Here's an example of how a strain gauge works.



$$R = \rho \frac{L}{A}$$



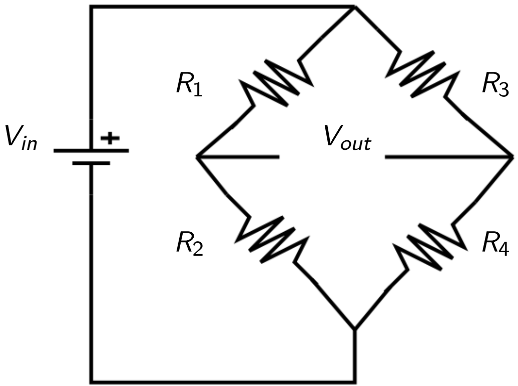
This is the resistance/temperature curve for a thermistor.

- If we want to put this variable resistor in a voltage divider, then we need to *choose* the other resistor.
- To make the output vary *over as large a range as possible* as the variable resistor goes from R_{min} to R_{max}, it turns out we want to choose the other resistor, R so that

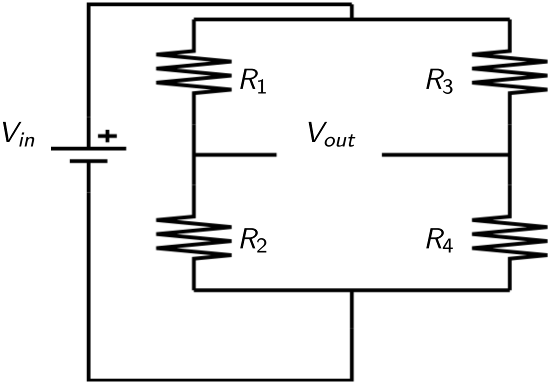
  $R = \sqrt{R_{min} \times R_{max}}$

Wheatstone bridges

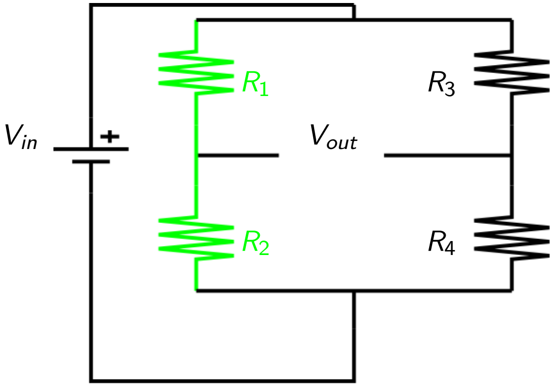
- A common type of circuit is a **Wheatstone bridge**.
- It is really a pair of voltage dividers using a common voltage source.
- It's usually operated with the output voltage at or close to zero.



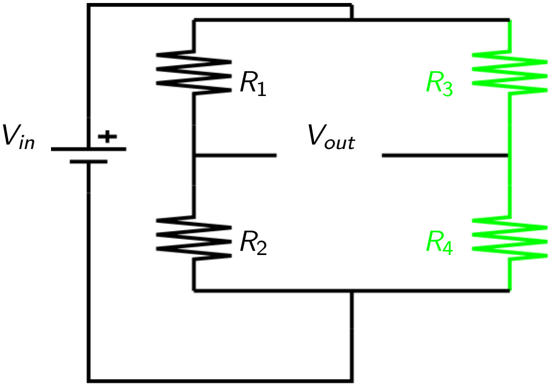
This is a Wheatstone bridge.



Here it's redrawn to show the two voltage dividers.

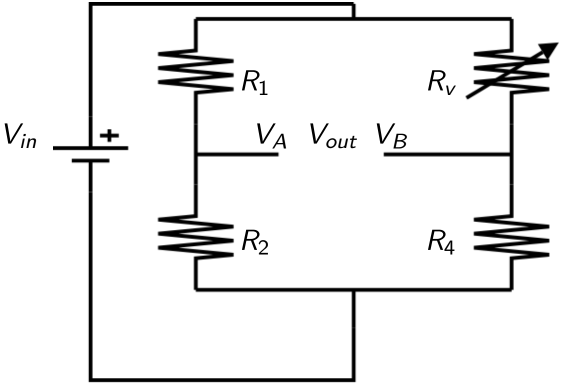


Here's one voltage divider.



Here's the other voltage divider.

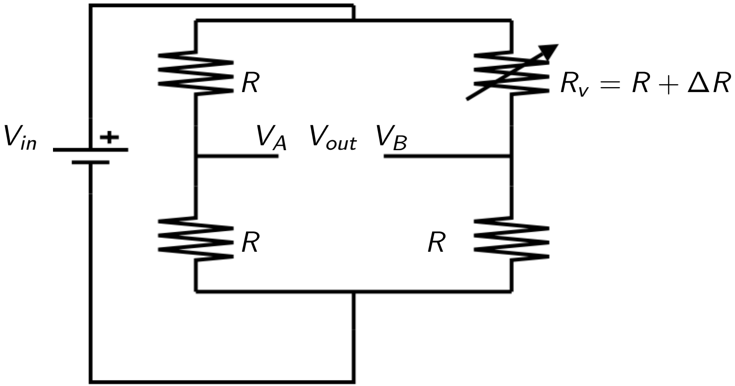
- Often a Wheatstone bridge is used with one resistor variable, such as a resistive sensor.
- Knowing the other resistors allows the variable one to be easily determined.
- The circuit is very sensitive to small changes in the variable resistor.



The variable resistor could be in any of the four positions; this is one example.

Balancing a Wheatstone Bridge

- When the bridge is "balanced", $V_o = 0$ or $V_A = V_B$.
- (This will happen when $\frac{R_1}{R_2} = \frac{R_v}{R_4}$.)
- For our diagram $R_1 \rightarrow R_2$ is the *reference* branch, and $R_v \rightarrow R_4$ is the *evaluation* branch.
- If R_v increases, V_B will decrease, and vice versa.
- For optimum performance, all resistors should be of the same order of magnitude.
- If using a resistive sensor, use a meter to measure resistance of sensor to get a correct order of magnitude.



If resistors are chosen to be equal, except for R_v, then the output voltage will vary with changes in R_v.

Specifically,

$V_A = V\frac{R}{2R} = V/2$

$V_B = V\frac{R}{2R+\Delta R} = V\frac{R+\Delta R/2-\Delta R/2}{2R+\Delta R} = V/2 - V\frac{\Delta R/2}{2R+\Delta R} \approx V/2 - V\frac{\Delta R/2}{2R}$

If no current flows between A and B then

$V_A - V_B \approx V\frac{\Delta R}{4R}$

which can be rearranged to give

$\Delta R \approx \frac{(V_A - V_B)}{V}4R$

So we can determine ΔR.

(This approximation is true as long as $\Delta R << R$)