Electronics
Resistive Sensors and Bridge Circuits

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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.
Switches in voltage dividers
Resistive sensors in voltage dividers
Wheatstone bridges

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

True if \( I_{out} \equiv 0 \)

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\[ R_1 = \infty \Rightarrow I = 0 \]

\[ V_2 = V_{out} = 0 \]
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\[ R_1 = \infty \Rightarrow I = 0 \]

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\[ R_1 = 0 \Rightarrow V_1 = 0 \]

\[ V_2 = V_{out} = V_{in} \]
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\[ \begin{align*}
R_1 &= 0 \Rightarrow V_1 = 0 \\
V_2 &= V_{out} = V_{in}
\end{align*} \]
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.
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\[ V_{out} = V_{in} \left( \frac{R_2}{R_1 + R_2} \right) \]

True if \( I_{out} \equiv 0 \)
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.
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Resistive sensors

\[ R = \rho \frac{L}{A} \]

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Resistive sensors

Resistance ($\Omega$)

Temperature ($^\circ$C)

(High temperature; $R_{min}$)

(Low temperature; $R_{max}$)

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 $R_{\text{min}}$ to $R_{\text{max}}$, it turns out we want to choose the other resistor, $R$ so that

$$R = \sqrt{R_{\text{min}} \times R_{\text{max}}}$$
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 $R_v$. 

$$R_v = R + \Delta R$$
Specifically,

\[ V_A = V \frac{R}{2R} = \frac{V}{2} \]

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

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 \( \Delta R \).

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