Electronics
Voltage Dividers

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May 31, 2017
Applications of Kirchhoff’s Voltage Law
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Voltage dividers
Variable resistors
Specific voltage dividers

Voltage divider (no load)
Voltage divider (with load RL)
Voltage dividers
Variable resistors
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Voltage divider (no load)
Voltage divider (with load $R_L$)

$V_s = V_{R_1} + V_{R_2}$
A voltage divider "divides" the supply voltage.
- **Voltage divider** "divides" the supply voltage
- It’s useful when you need a different voltage than the supply
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Since the current is the same in both resistors, the voltage is divided between the two; thus it is a **voltage divider**.
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Voltage dividers
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Specific voltage dividers

Voltage divider (no load)
Voltage divider (with load RL)

\[ V_s \]
\[ R_1 \]
\[ R_2 \]
\[ V_{out} \]
Usually a voltage divider is drawn like this so it looks like a ladder.
Usually a voltage divider is drawn like this so it looks like a ladder.
As you climb the ladder, the voltage increases.
Since $I_1 = I_2$, 

\[ V_{out} = \frac{R_2}{R_1 + R_2} V_s \]
Since \( I_1 = I_2 \), (by Kirchhoff’s current law,)

\[ \frac{V_s}{R_1 + R_2} = \frac{V_{out}}{R_2} \]
Since $I_1 = I_2$, (by Kirchhoff’s current law),
and $V_s = V_{R_1} + V_{R_2}$,
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so $V_s = I_1 R_1 + I_1 R_2$
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and $V_s = V_{R_1} + V_{R_2}$, (by Kirchhoff’s voltage law),
so $V_s = I_1 R_1 + I_1 R_2 = I (R_1 + R_2)$
Since $I_1 = I_2$, (by Kirchhoff’s current law), and $V_s = V_{R_1} + V_{R_2}$,(by Kirchhoff’s voltage law), so $V_s = I_1R_1 + I_1R_2 = I (R_1 + R_2)$

$I = \frac{V_s}{R_1 + R_2}$
So $V_{out} = V_2 = IR_2$
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\[ = V_s \left( \frac{R_2}{R_1 + R_2} \right) \]
If $R_1$ gets smaller, then

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

gets bigger.
Voltage dividers
Variable resistors
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Voltage divider (no load)
Voltage divider (with load \( RL \))

\[
V_{out} = V_s \left( \frac{R_2}{R_1 + R_2} \right)
\]
If $R_1$ gets bigger, then

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

gets smaller.
Voltage divider (no load)

If $R_1 = 5\,\Omega$, $R_2 = 10\,\Omega$, $V_s = 5\,V$,

$$V_{out} = V_s \left( \frac{R_2}{R_1 + R_2} \right) = 5 \left( \frac{10}{5+10} \right) = 3.3\,V.$$
Voltage divider (no load)

If $R_1 = 5\Omega$, $R_2 = 10\Omega$, $V_s = 5V$
Voltage divider (no load)

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$V_{out}$
Voltage divider (no load)

If $R_1 = 5\Omega$, $R_2 = 10\Omega$, $V_s = 5V$

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If \( R_1 = 5\Omega \), \( R_2 = 10\Omega \), \( V_s = 5\text{V} \)

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V_{out} = V_s \left( \frac{R_2}{R_1+R_2} \right) = 5 \left( \frac{10}{5+10} \right) = 3.3\text{V}
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Voltage divider (with load RL)

\[ V_s \]

Load will reduce the output voltage
Voltage divider (with load RL)
Voltage divider (with load $R_L$)

Some current goes through $R_2$, but some goes through $R_L$ so the effective value of $R_2$ is reduced.
If $R_1 = 5\Omega$, $R_2 = 10\Omega$, $V_s = 5\, V$ and $R_L = 10\, \Omega$
If \( R_1 = 5\Omega \), \( R_2 = 10\Omega \), \( V_s = 5\, V \) and \( R_L = 10\Omega \)

Parallel resistance of \( R_2 \) and \( R_L \) is \( \frac{R_2R_L}{R_2+R_L} \).
If $R_1 = 5\Omega$, $R_2 = 10\Omega$, $V_s = 5V$ and $R_L = 10\Omega$

Parallel resistance of $R_2$ and $R_L = \frac{R_2 R_L}{R_2 + R_L}$

$$= \frac{10 \times 10}{10 + 10} = 5\Omega$$
If $R_1 = 5\Omega$, $R_2 = 10\Omega$, $V_s = 5\, V$ and $R_L = 10\Omega$

Parallel resistance of $R_2$ and $R_L = \frac{R_2 R_L}{R_2 + R_L}$

$= \frac{10 \times 10}{10 + 10} = 5\Omega$

Thus $V_{out}$
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Parallel resistance of $R_2$ and $R_L = \frac{R_2 R_L}{R_2 + R_L}$

$$= \frac{10 \times 10}{10 + 10} = 5\Omega$$

Thus $V_{out}$

$$= V_s \frac{R_p}{R_1 + R_p} = 5 \left( \frac{5}{5+5} \right)$$
If $R_1 = 5\Omega$, $R_2 = 10\Omega$, $V_s = 5\, V$ and $R_L = 10\Omega$

Parallel resistance of $R_2$ and $R_L = \frac{R_2 R_L}{R_2 + R_L}$

$= \frac{10 \times 10}{10 + 10} = 5\Omega$

Thus $V_{out}$

$= V_s \frac{R_p}{R_1 + R_p} = 5 \left( \frac{5}{5+5} \right)$

$= 2.5\, V$
Variable resistors
Variable resistors

Often it is useful to have *variable* resistors in a circuit.
Variable resistors

Often it is useful to have *variable* resistors in a circuit. These are sometimes called *potentiometers* or *trimmers*. 
Voltage dividers
Variable resistors
Specific voltage dividers

$$V_{in}$$

$$R_1$$

$$I$$

$$R_2$$

$$I$$

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

True if $$I_{out} \equiv 0$$

$$R_1 + R_2 = \text{a constant.}$$
Here is a trimmer.
Here is a trimmer. The top line should look familiar.
The potentiometer has three pins.
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The resistance given is between the two end pins.
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The third pin is called the **wiper**.
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A small screwdriver can be used to move the wiper from one end to the other, or anywhere in between.
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The resistance given is between the two end pins.
The third pin is called the **wiper**.
A small screwdriver can be used to move the wiper from one end to the other, or anywhere in between.

*The resistance between the two end pins will be constant.*
The potentiometer has three pins. The resistance given is between the two end pins. The third pin is called the **wiper**. A small screwdriver can be used to move the wiper from one end to the other, or anywhere in between. *The resistance between the two end pins will be constant.* If you want a resistance which varies, just use the wiper and one end pin.
Voltage dividers
Variable resistors
Specific voltage dividers
Here’s a different view.
Here’s a different view. The wiper is in the middle.
From the top, this one has 10 dashes to represent intervals of roughly $R/10$. 
Voltage dividers
Variable resistors
Specific voltage dividers
This is a slightly different style.
This is a slightly different style. Note the graphical indication of the wiper.
The potentiometer can be used for a variable voltage divider.
The potentiometer can be used for a variable voltage divider. Connect the two ends of your supply to the two end pins.
The potentiometer can be used for a variable voltage divider. Connect the two ends of your supply to the two end pins. Measure the output voltage on the wiper.
The potentiometer can be used for a variable voltage divider. Connect the two ends of your supply to the two end pins. Measure the output voltage on the wiper. Adjusting the wiper will change the output voltage from one end of the supply to the other, or to anywhere in between.
Switches in voltage dividers
Switches in voltage dividers

One of the simplest forms of voltage divider is where one of the elements is a switch.
Switches in voltage dividers

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- A switch can be thought of as a resistor which can have a value of either zero or infinity.
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.
Voltage dividers
Variable resistors
Specific voltage dividers

Switches in voltage dividers
Resistive sensors in voltage dividers

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

True if $I_{out} \equiv 0$
Voltage dividers
Variable resistors
Specific voltage dividers

Switches in voltage dividers
Resistive sensors in voltage dividers

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

True if \( I_{out} \equiv 0 \)
Voltage dividers
Variable resistors
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Switches in voltage dividers
Resistive sensors in voltage dividers

\[ V_{in} \]

\[ R_1 \]

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

\[ V_2 = V_{out} = V_{in} \]

\[ R_2 \]

\[ I \]
Voltage dividers

Variable resistors

Specific voltage dividers

Switches in voltage dividers

Resistive sensors in voltage dividers

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

\[ V_{\text{in}} \]

\[ R_1 \]

\[ V_2 = V_{\text{out}} = 0 \]

\[ R_2 \]

\[ I \]
Voltage dividers
Variable resistors
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Switches in voltage dividers
Resistive sensors in voltage dividers

\[ V_{in} \]

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

\[ V_2 = V_{out} = V_{in} \]
Voltage dividers
Variable resistors
Specific voltage dividers

Switches in voltage dividers
Resistive sensors in voltage dividers

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

\[ V_{2} = V_{out} = 0 \]
So if one of the elements is a *switch*, the output varies between 0 and $V_{in}$. 

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- If either resistor in a voltage divider is *variable*, then a range of output voltages is possible.
Resistive sensors in voltage dividers

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

True if \( I_{out} \equiv 0 \)
If we want to put a variable resistor in a voltage divider, then we need to *choose* the other resistor.
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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
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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

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