Voltage and Current Division

EE 206 Circuits I

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Please visit Bison Academy for corresponding
lecture notes, homework sets, and solutions

Voltage Division

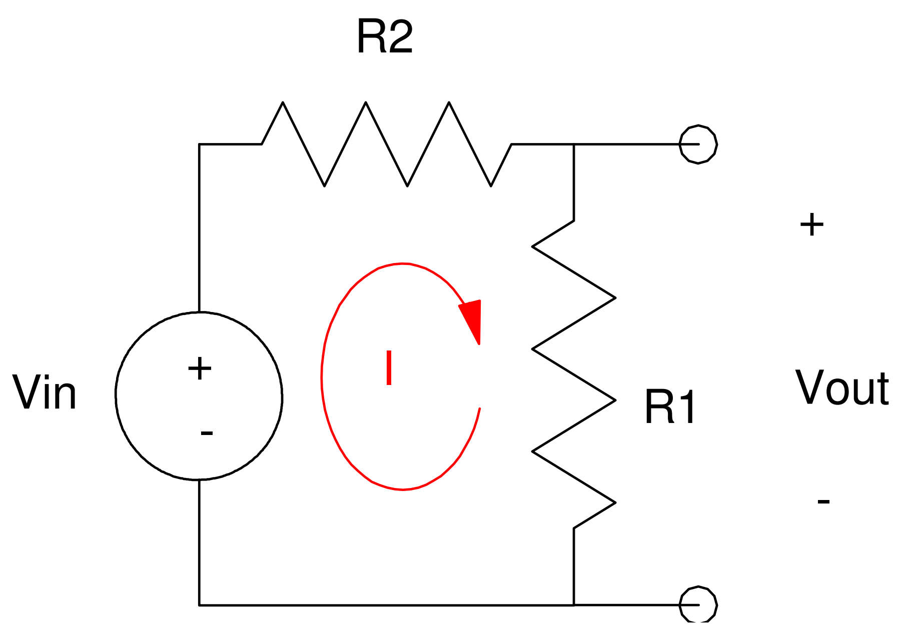
Problem: Generate a voltage that is X% of the input voltage.

Solution: Use two resistors in series:

$$I = \frac{V_{in}}{R_1 + R_2}$$

$$V_{out} = I \cdot R_1$$

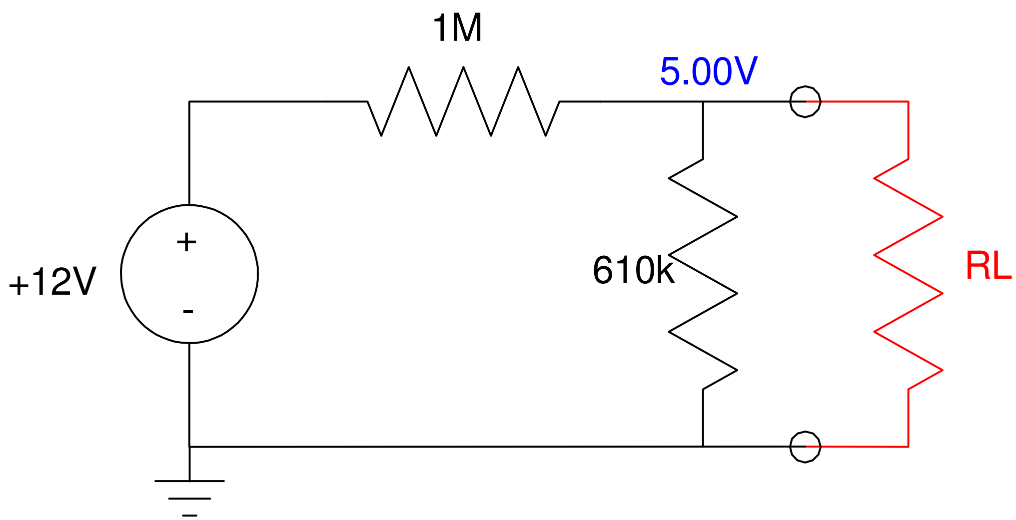
$$\boxed{V_{out} = \left(\frac{R_1}{R_1 + R_2}\right) V_{in}}$$



Example: Reduce the voltage from a car battery (13.2V) to 5V so that a microcontroller can read the voltage.

Solution: Let

$$\left(\frac{R_1}{R_1+R_2}\right) = \left(\frac{5V}{13.2}\right) = 0.379$$



To limit the current to a safe level, let

R2 = 1M Ohm

Then

R1 = 610k Ohms

Note

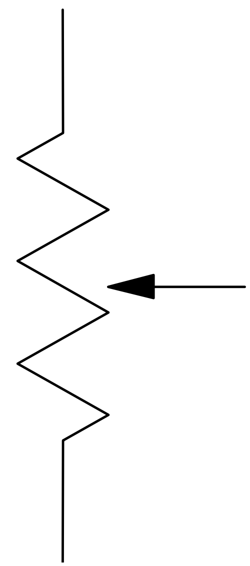
- This works as long as you don't use the 5V
- This works as long as RL >> 610k
- RL is in parallel with R1, changing R1 (and changing the voltage)

Potentiometers:

- A resistor with a center tap (wiper)
- Can be used as a variable resistor
- Can be used as a variable voltage

Potentiometer: Symbol

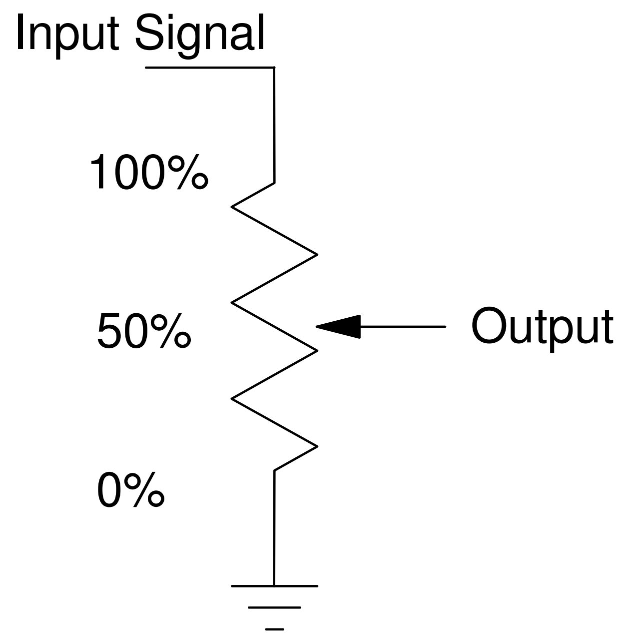
The symbol for a potentiometer reflects how it is built:



Symbol for a potentiometer. A resistor with an arrow indicating the center tap

Gain Adjustment

- Top = Signal
- Bottom = Ground
- Wiper: 0% to 100% of signal



Potentiometer used to attenuate an input signal from 0% to 100%

Loading

If there is no loading (RL = infinity) the voltage is linear

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

$$V_{out} = \left(\frac{aR}{aR+(1-a)R}\right) V_{in}$$

$$V_{out} = a \cdot V_{in}$$

If RL is finite, the voltage droops

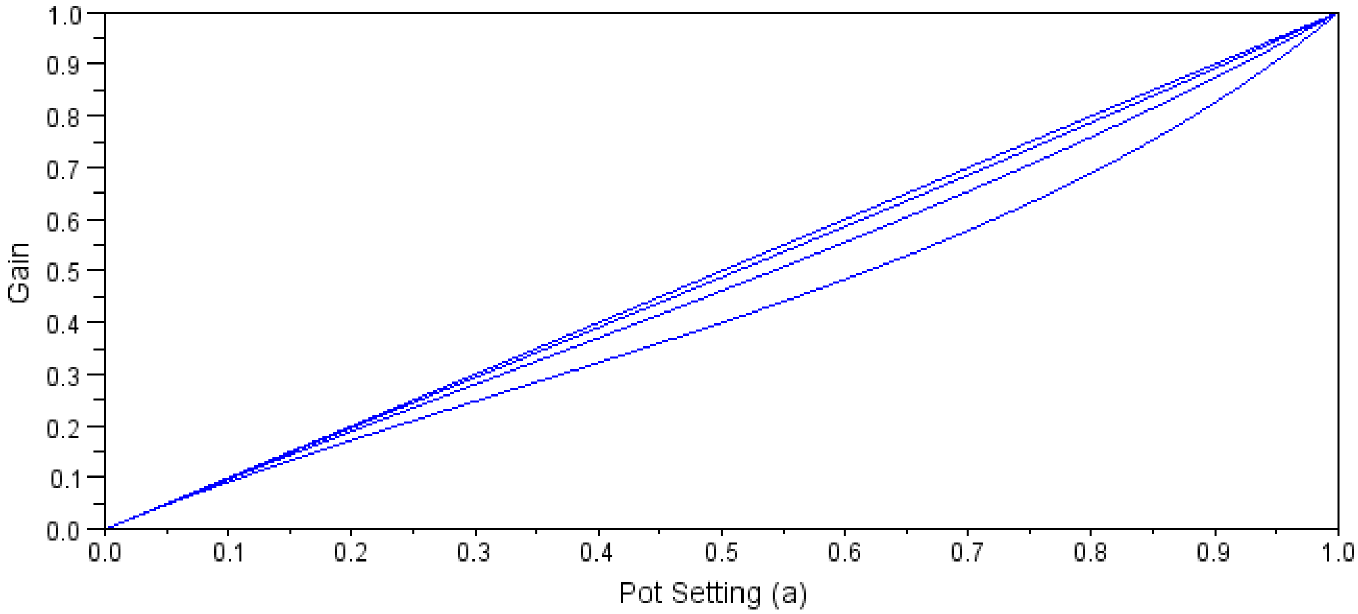
$$V_{out} = \left(\frac{R_1}{R_1+R_2}\right) V_{in}$$

$$R_1 = aR||R_L = \left(\frac{aR \cdot R_L}{aR+R_L}\right)$$

$$R_2 = (1-a)R$$

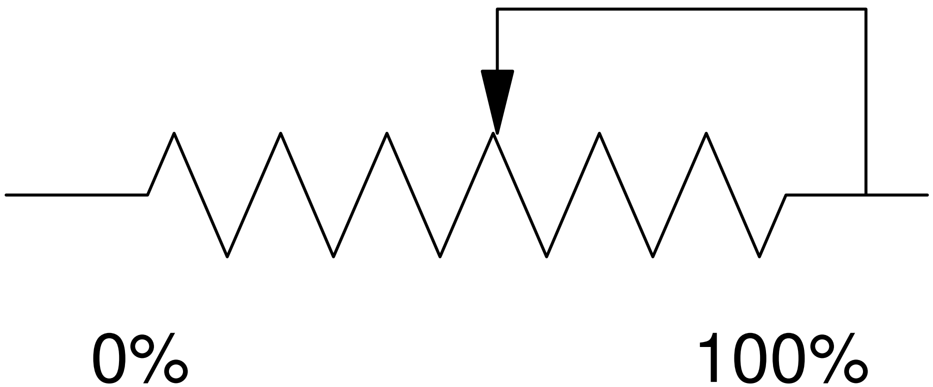
You can plot this in MATLAB with the following code:

```
R = 1000;
RL = 10000;
a = [0:0.01:1]'
Vin = 1;
R1 = a*R * RL ./ (a*R + RL);
R2 = (1-a)*R;
Vout = R1 ./ (R1 + R2);
plot(a,a,a,Vout);
xlabel('Pot Setting (a)');
ylabel('Gain');
```



Potentiometers Used as a Variable Resistor

- Allows you to adjust resistors in a circuit
- Convenient if you want to change values without having to rebuild the circuit
- R varies from 0% to 100% of the potentiometer's value



Potentiometer used as a variable resistor

Current Division

Problem: Find the currents I1 and I2

Solution: Find the voltage, V1

$$R = R_1 || R_2 = \left(\frac{1}{R_1} + \frac{1}{R_2}\right)^{-1}$$

$$V = IR = 100mA \cdot \left(\frac{1}{\frac{1}{R_1}+\frac{1}{R_2}}\right)$$

The currents are

$$I_1 = \frac{V_1}{R_1} = \left(\frac{\frac{1}{R_1}}{\frac{1}{R_1}+\frac{1}{R_2}}\right) \cdot 100mA$$

$$I_2 = \frac{V_1}{R_2} = \left(\frac{\frac{1}{R_2}}{\frac{1}{R_1}+\frac{1}{R_2}}\right) \cdot 100mA$$

Current Division

The current through a resistor x is

$$I_x = \left(\frac{\text{The admittance (1/R) of what you're measuring}}{\text{The total (sum) admttance}}\right) \cdot \text{Current In}$$

For this problem

$$I_1 = \left(\frac{\frac{1}{100}}{\frac{1}{100}+\frac{1}{200}}\right) \cdot 100mA = 66.7mA$$

$$I_2 = \left(\frac{\frac{1}{200}}{\frac{1}{100}+\frac{1}{200}}\right) \cdot 100mA = 33.3mA$$

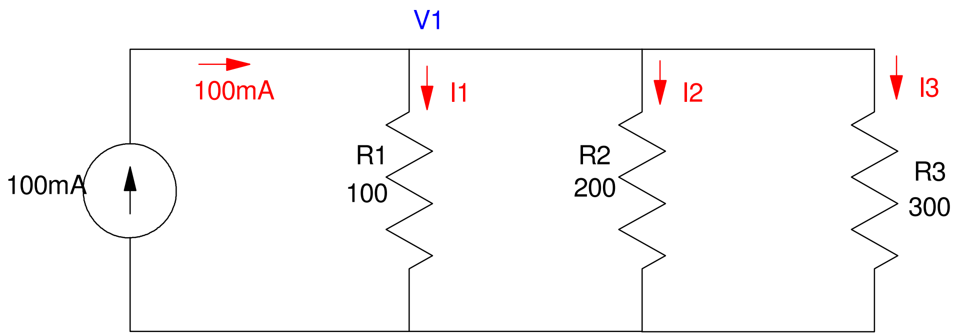
If you have more than one resistor, change it so that you have only two resistors

Current Division with 3 Resistors:

$$I_1 = \left(\frac{\frac{1}{100}}{\frac{1}{100} + \frac{1}{200} + \frac{1}{300}} \right) \cdot 100mA = 54.5mA$$

$$I_2 = \left(\frac{\frac{1}{200}}{\frac{1}{100} + \frac{1}{200} + \frac{1}{300}} \right) \cdot 100mA = 27.3mA$$

$$I_3 = \left(\frac{\frac{1}{300}}{\frac{1}{100} + \frac{1}{200} + \frac{1}{300}} \right) \cdot 100mA = 18.2mA$$



Note that

I1 + I2 + I3 = 100mA

Current Out = Current In