# Fundamentals of Electrical Engineering

## Circuit Interconnection Laws

- Kirchhoff's Current Law
- Kirchhoff's Voltage Law

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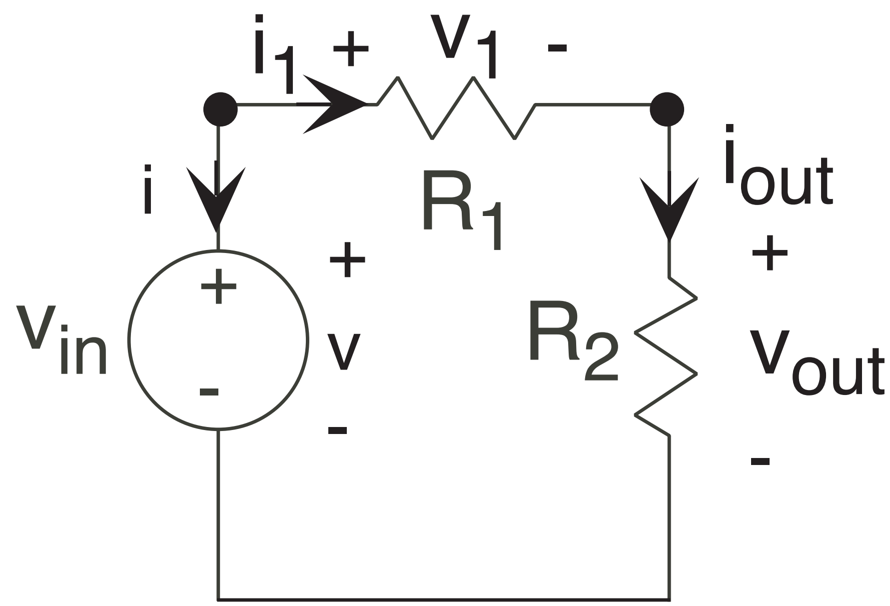
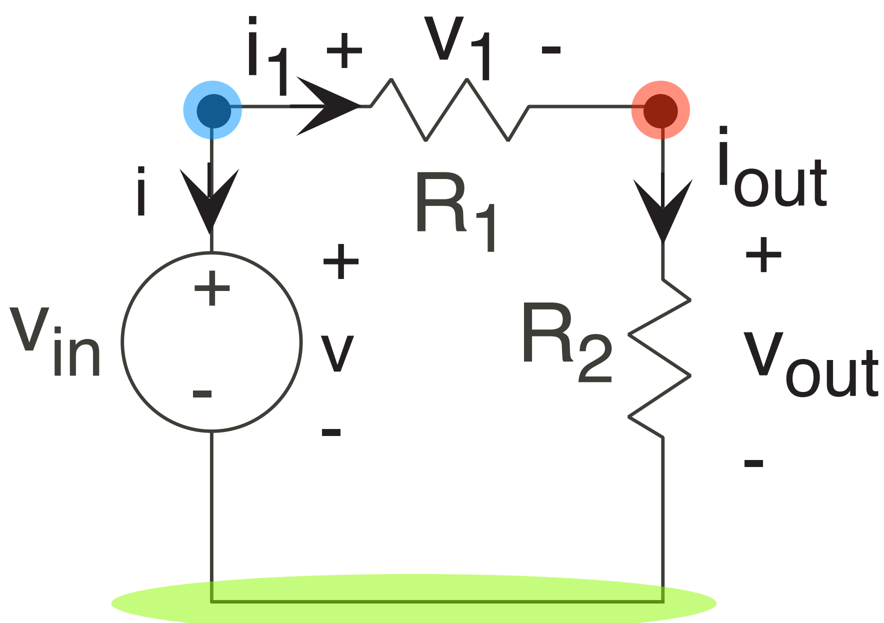
# A Simple Circuit




$$v(t) = v_{\text{in}}(t)$$
$$v_1 = R_1 i_1(t)$$
$$v_{\text{out}}(t) = R_2 i_{\text{out}}(t)$$

# Kirchhoff's Current Law (KCL)

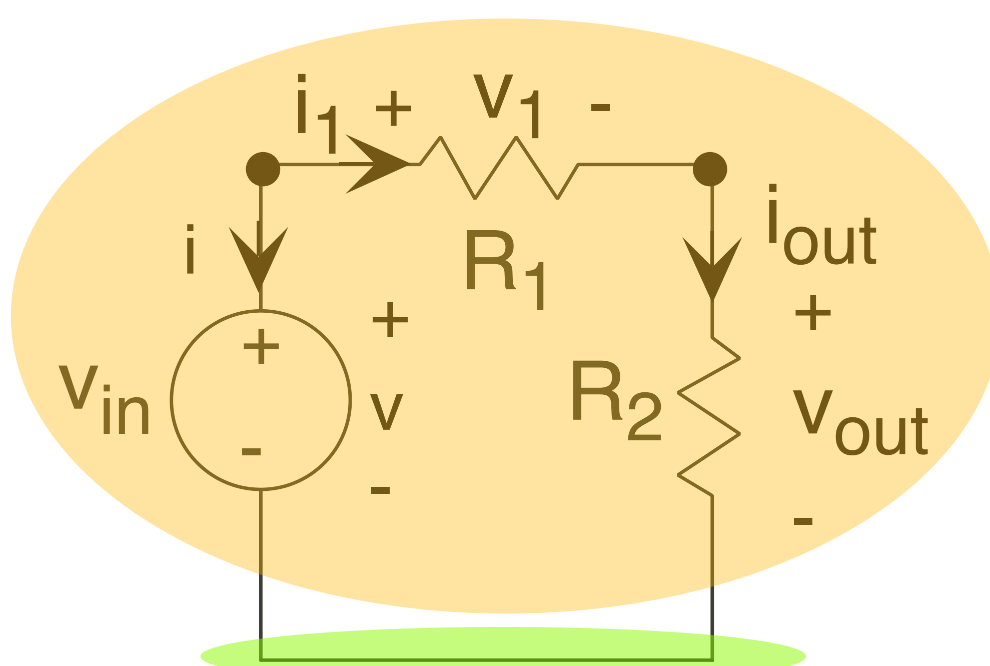
- The sum of currents entering a node (or leaving a node) equals zero




$$-i - i_1 = 0$$

$$i_1 - i_{out} = 0$$

~~$i + i_{out} = 0$~~




For an *n* node circuit, only *n*-1 KCL equations are linearly independent

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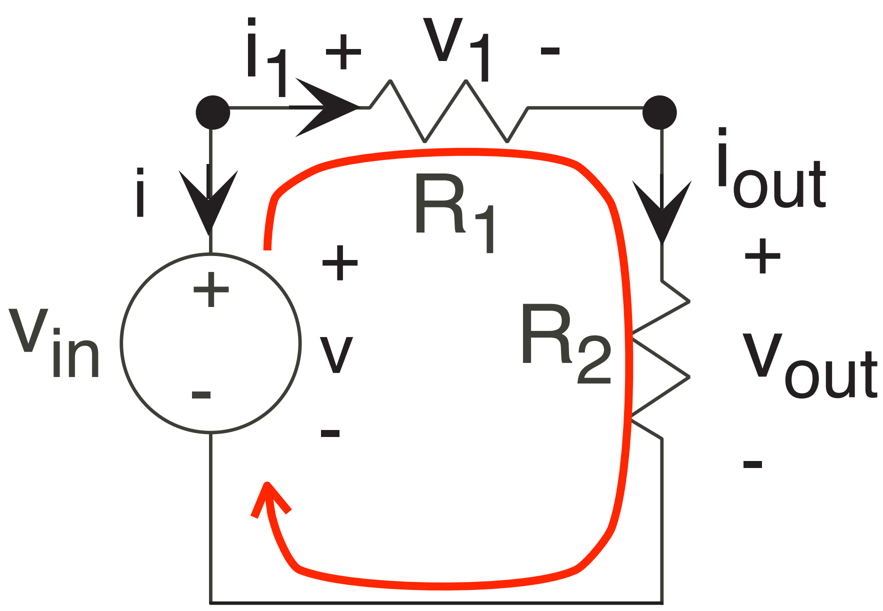
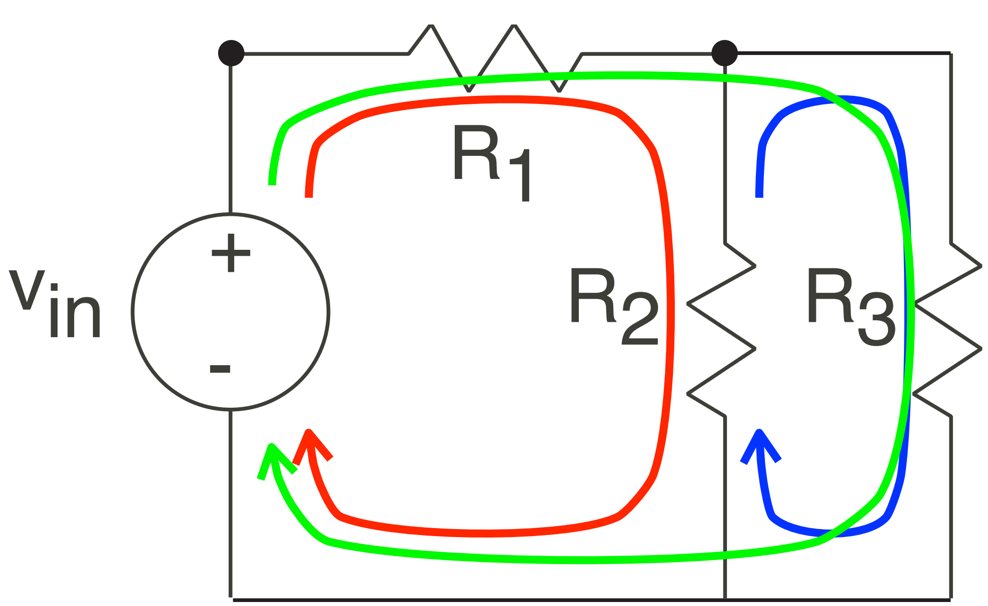
# Kirchhoff's Voltage Law (KVL)

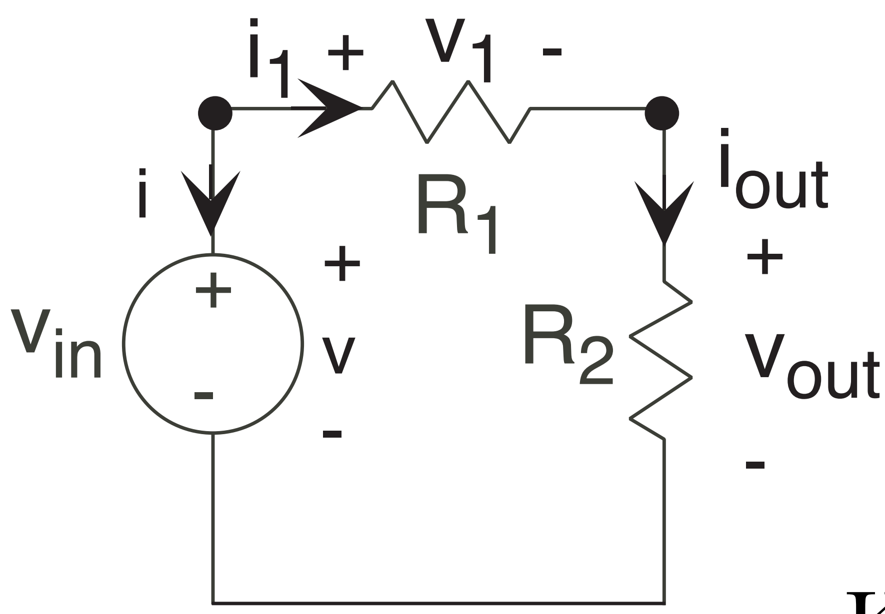
- The sum of voltages around any closed loop equals zero




$$v_1 + v_{\mathrm{out}} - v = 0$$



# Solving the Circuit




$v$-$i$ relations:

$$v(t) = v_{\text{in}}(t)$$
$$v_1 = R_1 i_1(t)$$
$$v_{\text{out}}(t) = R_2 i_{\text{out}}(t)$$

KCL equations:

$$-i - i_1 = 0$$
$$i_1 - i_{\text{out}} = 0$$

KVL equation: $v_1 + v_{\text{out}} - v = 0$

After some manipulation, it is *easily* shown that

$$\boxed{v_{\text{out}}(t) = \frac{R_2}{R_1 + R_2} v_{\text{in}}(t)}$$

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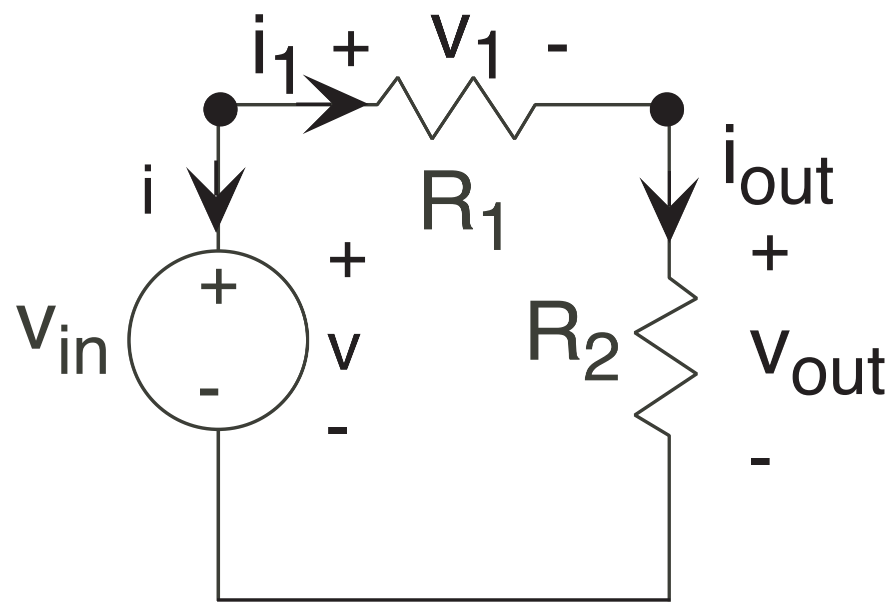
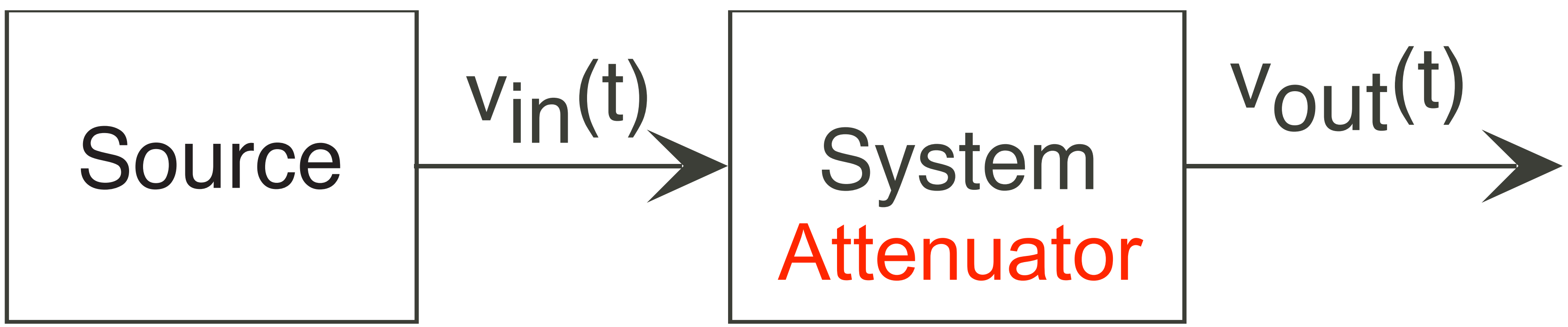
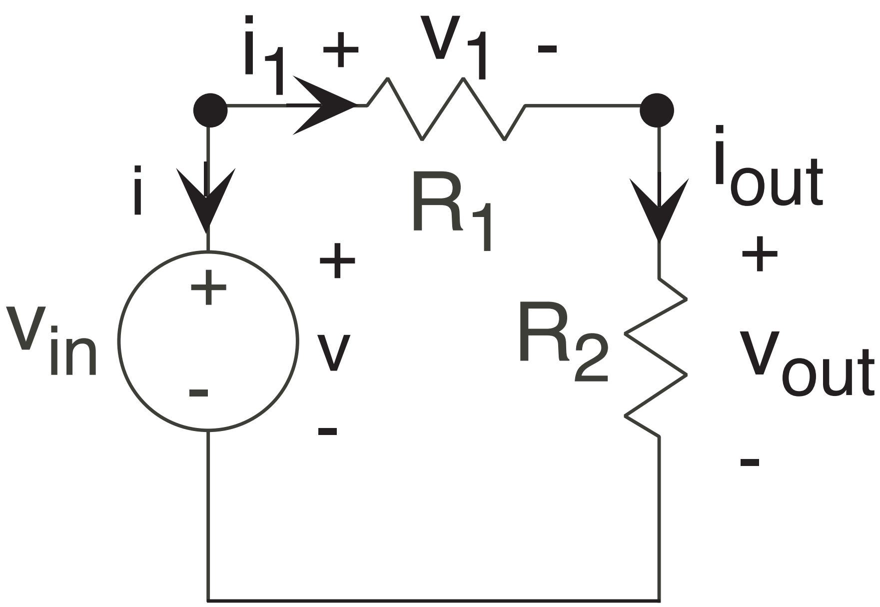
# What Does Our Circuit Do?




$$v_{\text{out}}(t) = \frac{R_2}{R_1 + R_2} v_{\text{in}}(t)$$

# Circuits and Power




$$p_2(t) = \frac{v_{\text{out}}^2}{R_2} = \frac{R_2}{(R_1+R_2)^2} v_{\text{in}}^2$$

$$p_1(t) = \frac{v_1^2}{R_1} = \frac{R_1}{(R_1+R_2)^2} v_{\text{in}}^2$$

Since $i_{\text{out}} = \frac{v_{\text{out}}}{R_2}$, $i_{\text{out}} = \frac{v_{\text{in}}}{R_1+R_2}$

Now $i = -i_{\text{out}}$, which means $p_{\text{source}}(t) = -\frac{v_{\text{in}}^2}{R_1+R_2}$

*No net power produced or consumed!*

$$\boxed{\sum_k v_k(t) \cdot i_k(t) = 0}$$

# Circuit Interconnection Laws

- Along with the *v*-*i* relations, KVL and KCL *always* provide exactly the number of equations needed to solve *any* circuit
- Need streamlined methods for solving circuit equations
- Later, we will show that only KVL and KCL are needed to show that circuits conserve power