Analog Electronics I: resistors & V-dividers

Tuesday, September 15, 2020 8:18 PM

pg. 1-44 in Horowitz & Hill, The Art of Electronics.

2 Fundamental laws:

Ohm's law — we're using this for our measurement.

Kirchoff's laws

$$V = I R$$

- V: Voltage potential
- I: flow of e^-
- R: Resistance to e^- flow.

Analogy to hydrodynamics:

$$H = J \cdot R$$

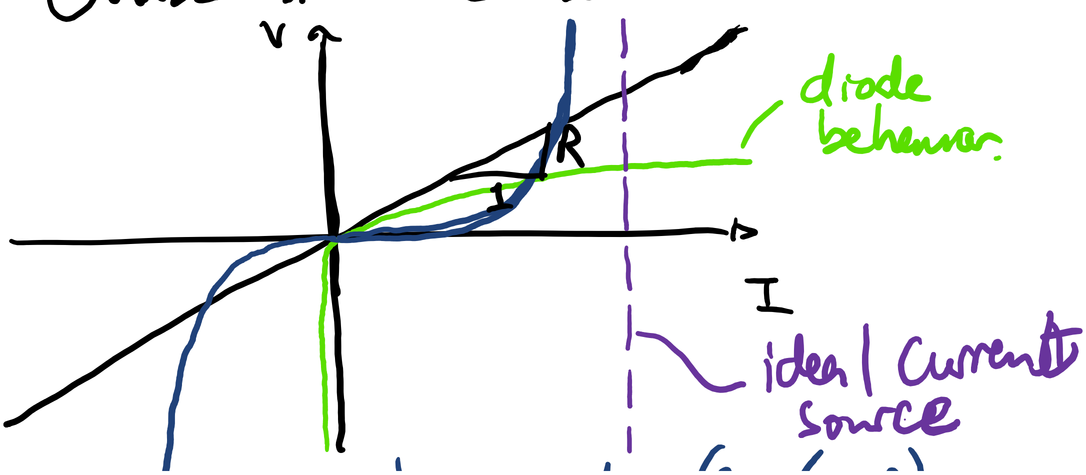
- H: hydrostatic pressure
- J: fluid flux
- R: Hydrodynamic resistance

"A Volt pushes an Amp through an Ohm."

Volt — potential energy / unit charge.

*Voltage is measured relative to a reference potential.

"Ohmic" vs. "non-Ohmic" behavior



source

non-linear resistor (e.g. (amp)

Power: $P = IV = I^2R$ ← Ohm's law.

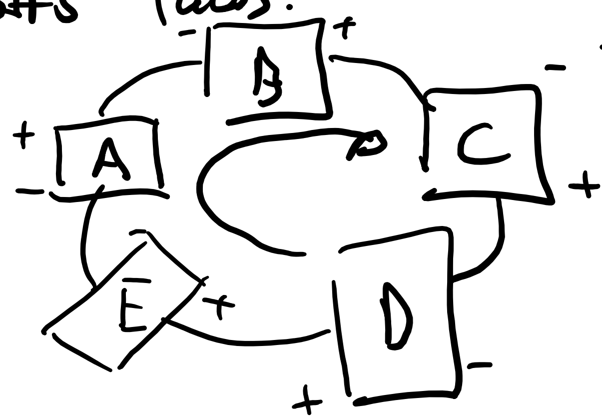
I : current, charge / time

V : work or energy / charge

$[IV]$ $\frac{\text{work}}{\text{time}} = \frac{\text{energy}}{\text{time}} = [P]$.

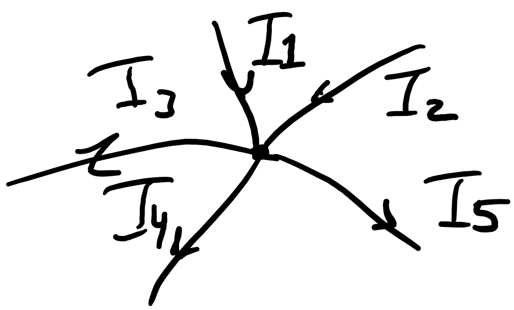
Kirchoff's laws:

I:



* sum of voltages around a closed loop is 0.

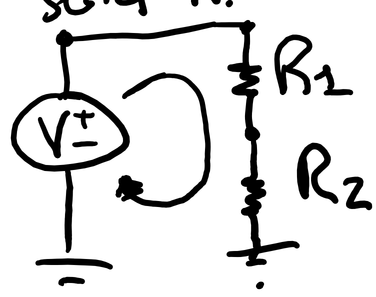
II



* Sum of the currents at a node is 0.

Examples:

Series R:



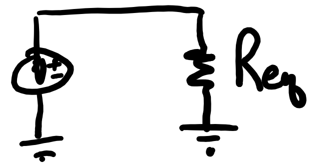
$I_{tot} = I_1 = I_2$ by K2.

$V_{tot} = V_1 + V_2$ (K I)

An eq. resistance:

$V_{tot} = I_t R_{eq} = I_t R_1 + I_t R_2$

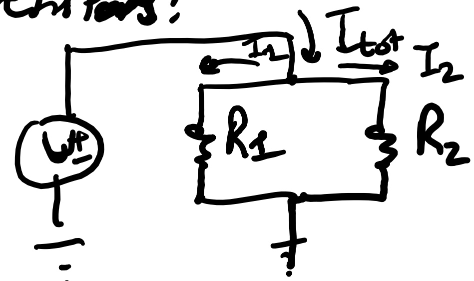
... eq. resistance:



$V_{tot} = I_t R_{eq} = I_t R_1 + I_t R_2$

$\Rightarrow R_{eq} = R_1 + R_2.$

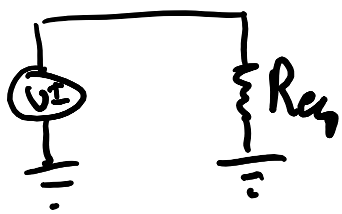
parallel resistors:



$I_{tot} = I_1 + I_2. \quad (K2)$

$V_{tot} = V_1 = V_2 \quad (K1).$

equivalent R:



$V_{tot} = I_{tot} \cdot R_{eq} = V_1 = V_2$

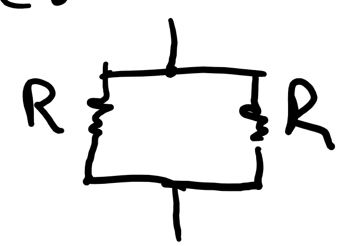
$I_{tot} R_{eq} = I_1 R_1 = I_2 R_2$

$I_{tot} = I_1 + I_2; \quad I_1 = \frac{V}{R_1}; \quad I_2 = \frac{V}{R_2};$

$I_{tot} = \frac{V}{R_{eq}}$

$$\frac{V}{R_{eq}} = \frac{V}{R_1} + \frac{V}{R_2} \Rightarrow \boxed{R_{eq} = \frac{R_1 R_2}{R_1 + R_2}}.$$

Consider these cases:



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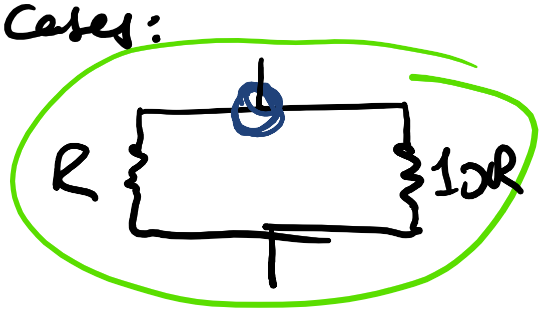

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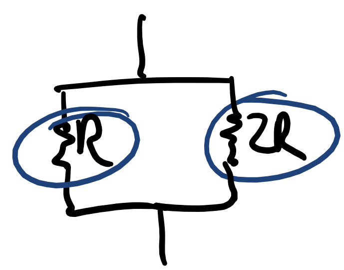
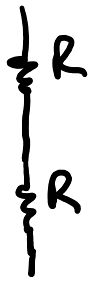


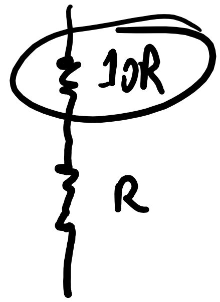
$R \| R \Rightarrow R_{eq} = \frac{R^2}{2R} = \frac{R}{2}.$

$R \| 10R \Rightarrow R_{eq} = 10R^2 \ldots = 10R^2 \ldots R$

$\overline{R+10R}$ $\overline{11R} \simeq R.$

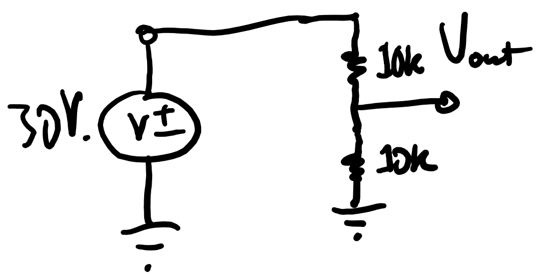
$R_{eq} = 2R$





$R_{eq} = 11R \simeq 10R.$

V-divider (a device)

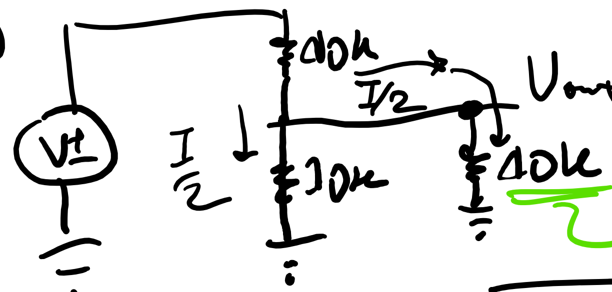


Solve for V_{out}:

$$I = \frac{V_{in}}{(R_1+R_2)} ; \quad V_{out} = IR_2$$

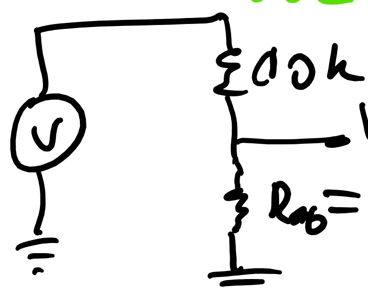
$$V_{out} = \frac{V_{in} R_2}{R_1+R_2} = \frac{V_{in}}{2}.$$

Using device:



"Resistive load."

100k.



$V_{out} = \frac{V}{3}.$

$R_{eq} = 10k \| ~~10k~~ 100k = ~~5k~~ 10k.$