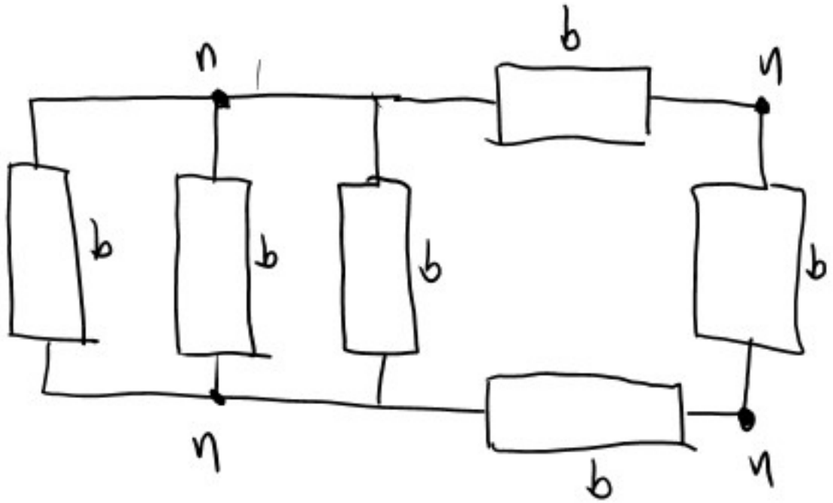
Electric circuit: a interconnection of circuit elements linked together in a closed loop




Network topology: node (n), branch (b), loop (l)

branch : a single element

node: point of connection between 2 or more branches

loop: a closed path
independent loop (mesh)

$n = 4,\ b = 6,\ l = 3,\quad b = n + l - 1$

6 4 3

mobile carrier in electric circuit

charge : Q (electron)

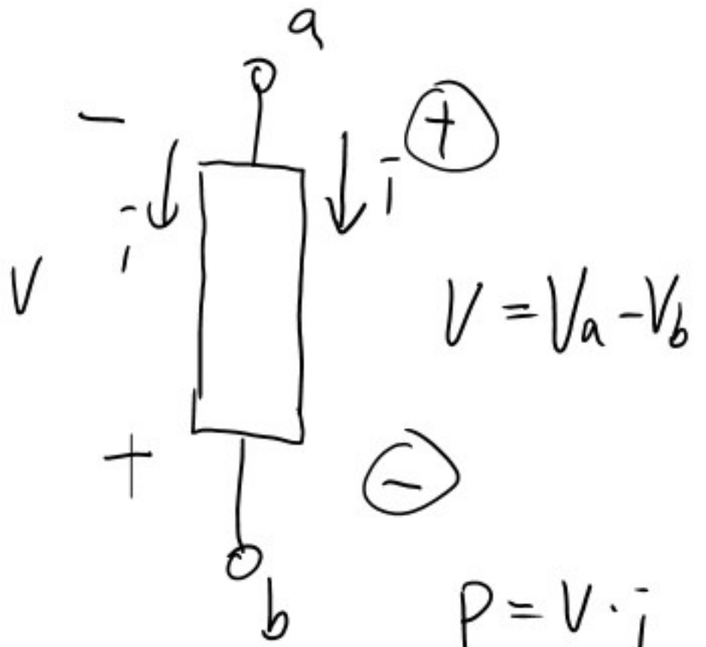
I changes w.r.t. time

D.C

current $I = \frac{dQ}{dt}$ I or i(t)

voltage $V = \frac{dw}{dQ}$ V or v(t)

power. $P = \frac{dw}{dt} = VI$




$V = V_a - V_b$

$P = V \cdot i$

power absorbed by the element.

$P = V \cdot i$

power supplied by the element

$i = 2A$ $\quad i = -2A$

$V = 4V = V_a - V_b$ $\quad V = -4V = V_a - V_b$

$\Rightarrow V_b - V_a = 4V$

the sign indicates the current direction / which end has the higher potential / a circuit element supplies or absorbs energy

Kirchhoff's law:

current law (KCL) = the algebraic sum of the current into a "node" is zero

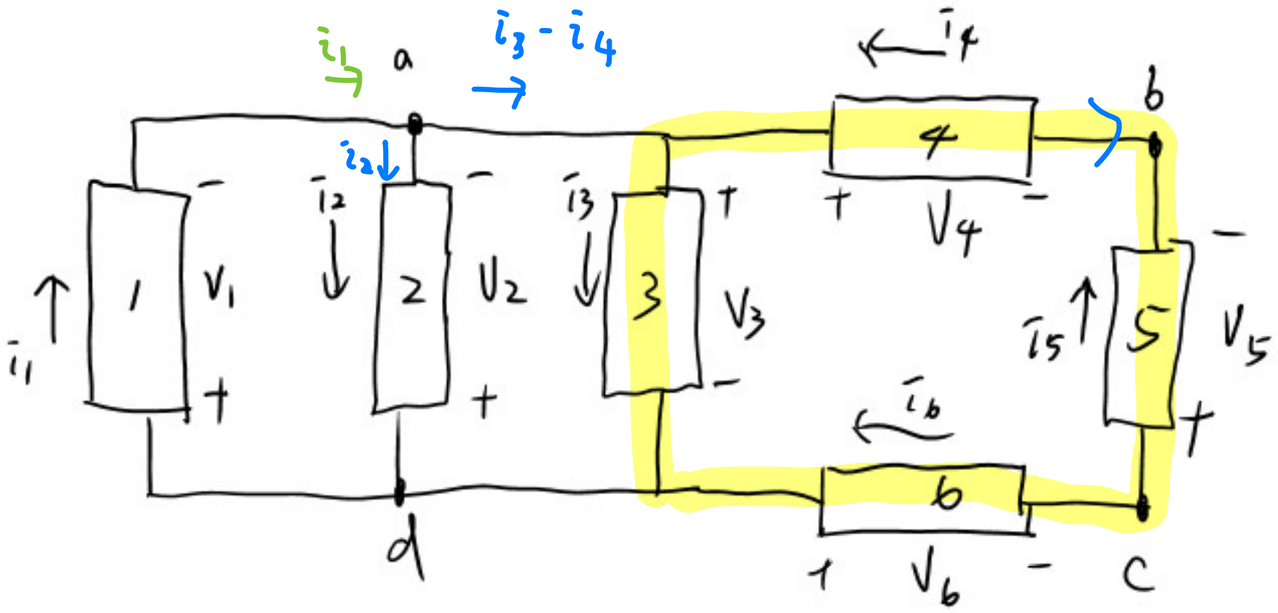
$$\sum_{n=1}^{N} \bar{I}_n = 0$$

conservation of charge

voltage law (KVL) = the algebraic sum of the voltage around a loop is zero

$$\sum_{n=1}^{N} V_n = 0$$

conservation of energy



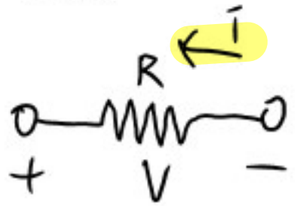

KCL: node a : $\bar{I}_1 - \bar{I}_2 - \bar{I}_3 + \bar{I}_4 = 0$

KVL: loop 4-5-6-3 : $-V_4 + V_5 + V_6 + V_3 = 0$

passive element (absorb energy) : resistor, capacitor.

1. resistor 電阻 (R) ohm law Ω


$V = i \cdot R$

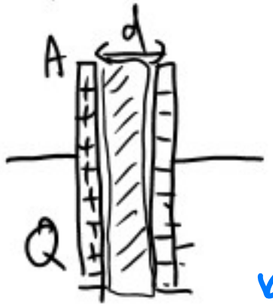



$V = -i \cdot R$

metal

$R = \rho \frac{L}{A}$ (L: length, ρ: resistivity, A: cross sectional area)

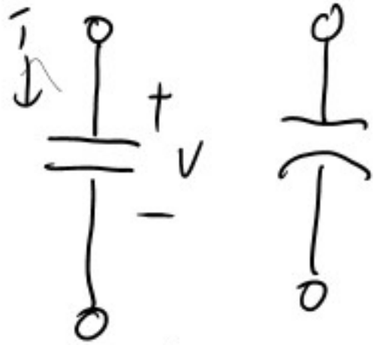

2. capacitor 電容 (C) . energy storage as E




$C = \varepsilon \frac{A}{d}$

$Q = CV$

$i(t) = C \cdot \frac{dV(t)}{dt}$






$i = C \cdot \frac{dV}{dt}$

parallel plates

note:
1. voltage cahnge (charging, discharging) $dV(t)/dt$
2. In DC, act as open circuit (i=0)
3. in AC, act as resistor with values varying as frequency
4. actual capacitor has high resistivity (over Mohm)
5. in eelctric circuit, C is in uF ~pF

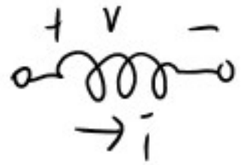
$10^{-6}$ $10^{-12}$ megaohm ($10^6$)

not perfectly linear, only upon a specific I interval

capacitor 1. internal property in transistor

2. widly used in the design of amplifier and filter.

3. inductor (energy storage) 電感 store energy as magnetic field B




$v(t) = L \frac{di(t)}{dt}$ in general, not used in electronic circuit for its size

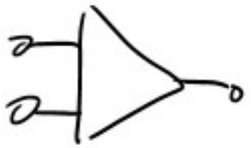
linear

nonlinear

nonlinear element

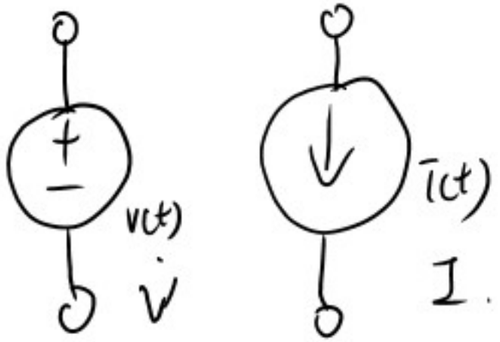
diode 

transistor 

operational amplifier (OPAMP) 

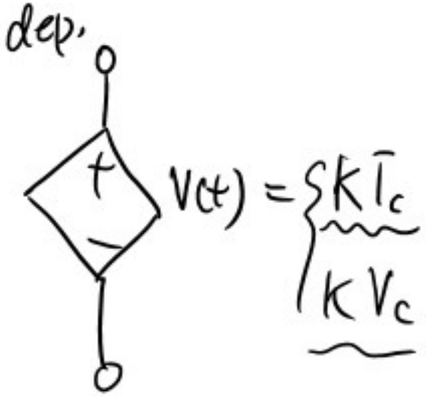
relationship bw V and I ?

active element (supply energy) = independent or dependent voltage or current source




ind.

dep.




current controlled voltage source (CCVS)

voltage controlled voltage source (VCVS)

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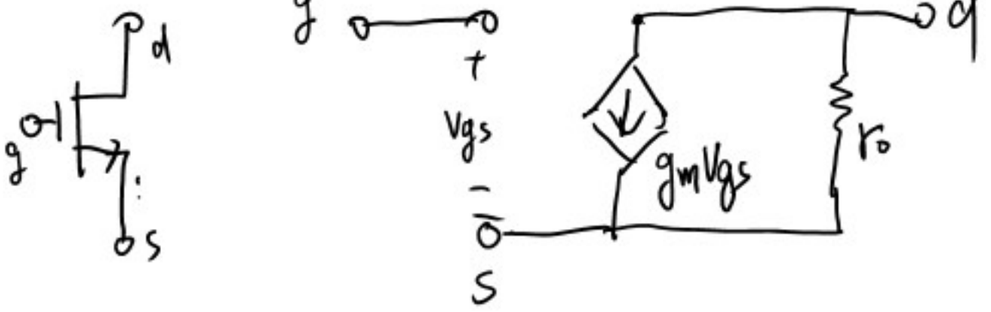
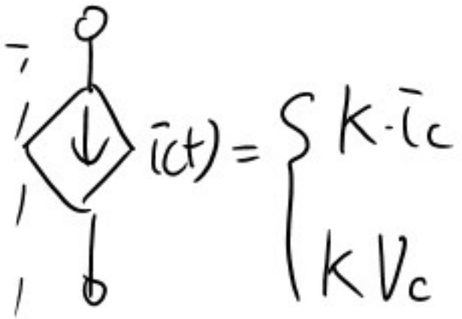
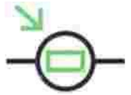
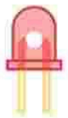
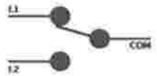
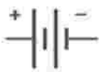
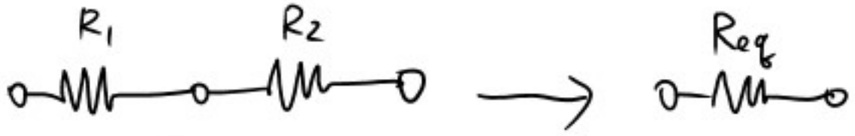
circuit model of a transistor



| ACTIVE | | | PASSIVE | | |
|---|---|---|---|---|---|
| Transistor |  |  | Resistor |  |  |
| Diode |  |  | LDR |  |  |
| LED |  |  | Thermistor |  |  |
| Photodiode |  |  | Capacitor |  |  |
| Integrated Circuit |  | - | Inductor |  |  |
| Operational Amplifier |  |  | Switch |  |  |
| Seven Segment Display |  |  | Variable Resistor |  |  |
| Battery |  |  | Transformer |  |  |

series, 

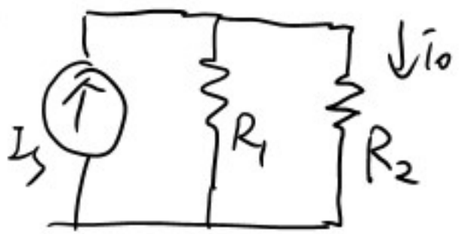
$R_{eq} = R_1 + R_2$

parallel 

$R_{eq} = \frac{R_1 R_2}{R_1 + R_2}$ $\quad \frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2}$

voltage divider 

$V_o = \frac{R_1}{R_1 + R_2} V_s$, $\quad R_1 = 1\Omega$, $R_2 = 3\Omega$, $\quad V_o = \frac{1}{3+1} V_s = \frac{3}{4} V_s$

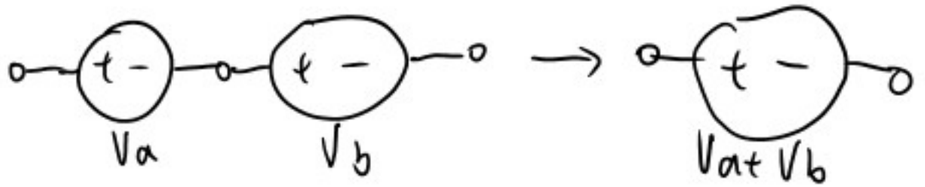
current divider 

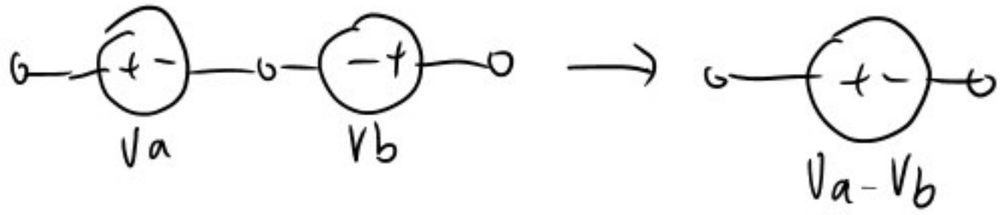
$i_o = \frac{R_1}{R_1 + R_2} \cdot I_s$ $\quad i_o = \frac{1}{4} I_s$

equivalent capacitor ?

source

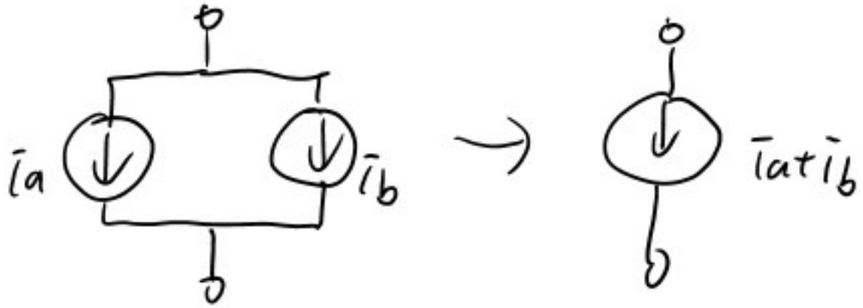
voltage in series

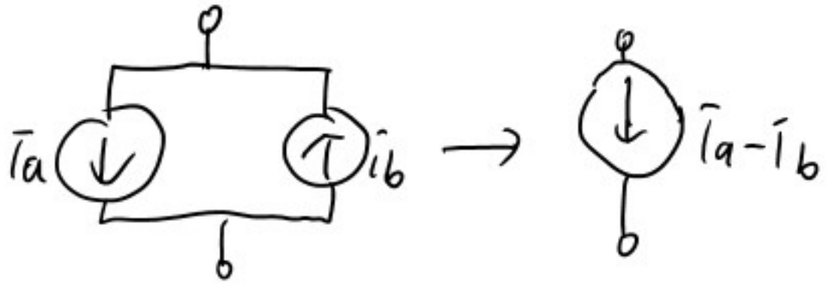


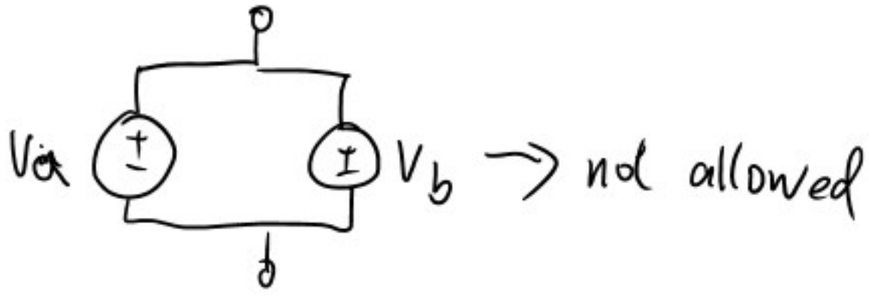



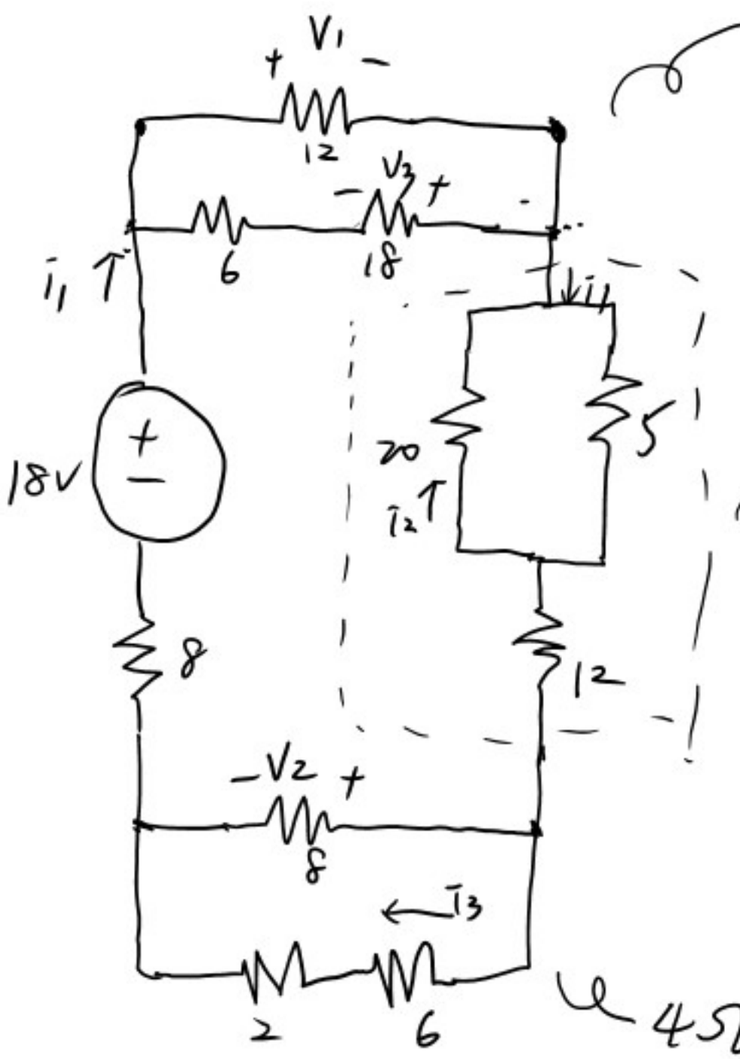


current source in parallel

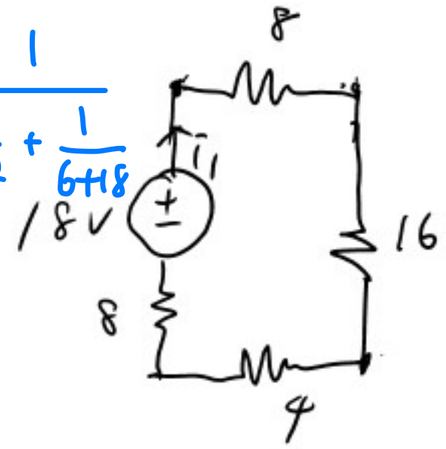





$8\Omega = \dfrac{1}{\frac{1}{12}+\frac{1}{6+18}}$




$\bar{I}_1 = \dfrac{18}{8+16+8+4} = \dfrac{18}{36} = 0.5A$ (Ohm's Law)

$V_1 = 18 \cdot \dfrac{8}{8+16+4+8} = 4V$

$16\Omega = \dfrac{1}{\frac{1}{20}+\frac{1}{5}} + 12$

$V_2 = 18 \cdot \dfrac{4}{8+16+4+8} = 2V$

$\bar{I}_2 = (-\bar{I}_1)\cdot\dfrac{5}{20+5} = -0.1A$

$V_3 = \dfrac{18}{6+18}(-V_1) = \dfrac{18}{24}(-4) = -3V$

$\bar{I}_3 = \bar{I}_1 \dfrac{8}{8+8} = 0.25A$

$4\Omega = \dfrac{1}{\frac{1}{8}+\frac{1}{2+6}}$