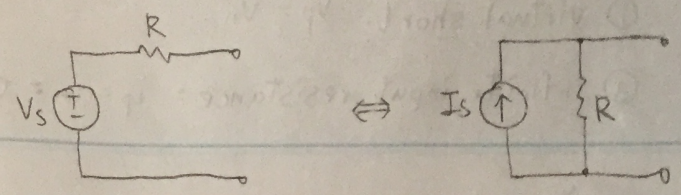
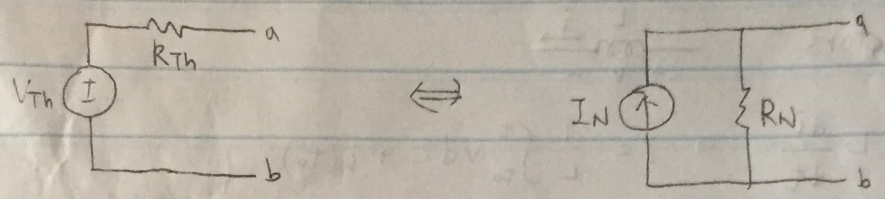
Source Transformation



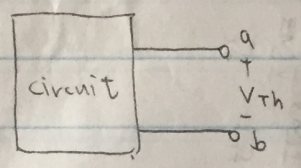
$I_s = \frac{V_s}{R}$

Thevenin and Norton Equivalent

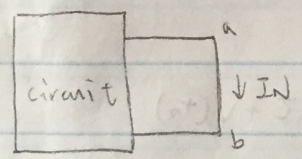


Thevenin equivalent Norton equivalent

V_{Th} : open circuit



I_N : short circuit



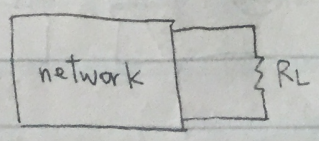
R_{Th} : ① $R_{Th} = \frac{V_{Th}}{I_N}$

② Eliminate sources : short the voltage sources, open the current sources

③ Apply a test source (when there is dependent source)

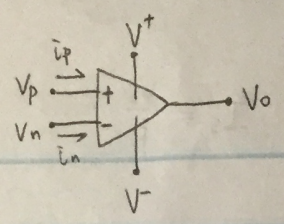
Maximum Power Transfer

For what R_L is the power maximized ?



R_L = Thevenin resistance.

Operational Amplifier

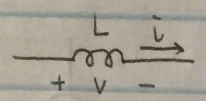


① virtual short : $V_p = V_n$

② infinite input resistance : $i_p = i_n = 0$

Inductors and Capacitors

* Inductors



$$V = L\frac{di}{dt} \Rightarrow i = \frac{1}{L}\int_{t_0}^{t} v\,d\tau + i(t_0)$$

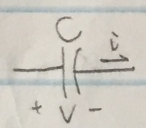
steady state : behaves like short circuit ($i = \text{const}$, $v = 0$)

energy stored in an inductor : $\frac{1}{2}Li^2$

inductors in series : $L_{eq} = \sum_{i=1}^{n} L_i$

parallel : $\frac{1}{L_{eq}} = \sum_{i=1}^{n} \frac{1}{L_i}$

* Capacitors



$$i = C\frac{dv}{dt} \Rightarrow v(t) = \frac{1}{C}\int_{t_0}^{t} i\,d\tau + v(t_0)$$

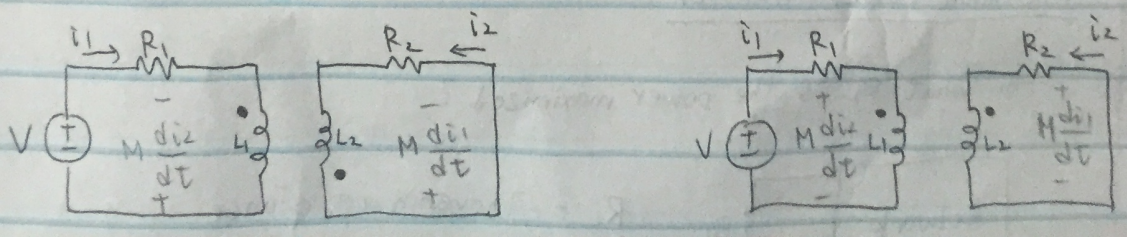
steady state : behaves like an open circuit ($i = 0$, $v = \text{const}$)

energy stored in a capacitor : $\frac{1}{2}CV^2$

capacitors in series : $\frac{1}{C_{eq}} = \sum_{i=1}^{n} \frac{1}{C_i}$

parallel : $C_{eq} = \sum_{i=1}^{n} C_i$

* Mutual inductance

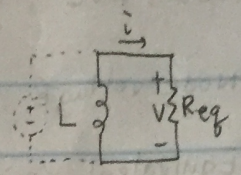


First-order Circuit

Natural Response (sources have been turned off abruptly)

RL:

$$i(t) = i_0 e^{-\frac{t}{\tau}} \quad , \tau = \frac{L}{R}$$

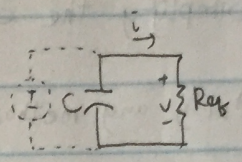


$$i_0 = i_L(0^+) = i_L(0^-)$$

$$v(0^-) = 0 \ , \ v(0^+) = i_0 \cdot R_{eq}$$

RC:

$$v(t) = V_0 e^{-\frac{t}{\tau}} \quad , \tau = RC$$



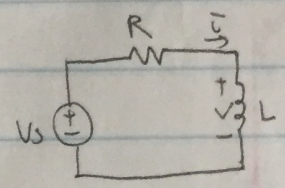
$$i(t) = \frac{v(t)}{R_{eq}}$$

$$V_0 = V_c(0^+) = V_c(0^-)$$

Step Response (source is sudden applied to a circuit)

RL:

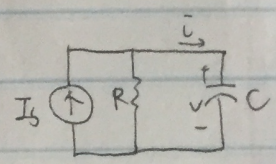
$$i(t) = \frac{V_s}{R}\left(1 - e^{-\frac{t}{\tau}}\right)$$



$$v(t) = V_s e^{-\frac{t}{\tau}}$$

RC:

$$v(t) = I_s R\left(1 - e^{-\frac{t}{\tau}}\right)$$



$$i(t) = I_s e^{-\frac{t}{\tau}}$$

General Solution

$$x(t) = \underbrace{x_\infty}_{\text{① steady state value}} + \underbrace{(x(t_0) - x_\infty)}_{\text{② initial value}} \cdot e^{-\frac{t-t_0}{\underbrace{\tau}_{\text{③ time constant}}}}$$

Energy dissipated by the resistor

$$p = iv$$

$$\Delta W = \int_{t_0}^{t_1} p \, dt$$

Solve a circuit

- a. KCL, KVL, ☆Ohm's Law
- b. Node voltage / Mesh current
- c. Equivalent resistance
- d. Source transformation

① Simplify the circuit (the part which we are not interested in) [c. d.]

② Apply any method you are familiar with [a, b.]

③ For <u>first-order circuits</u>,

Solve two circuits
- before $t=0$
- after $t=0$

(sources are added/removed at $t=0$)