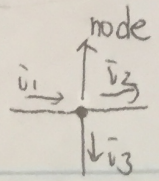
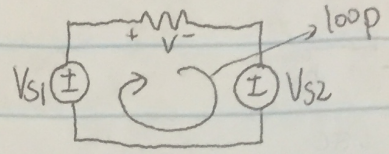
Basic Tools

1. KCL: $\sum_{Node} i_j = 0$



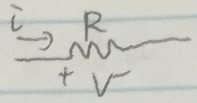
$-i_1 + i_2 + i_3 = 0$

2. KVL: $\sum_{Loop} V_k = 0$



$V_{S2} - V_{S1} + V = 0$

3. Ohm's Law: for a resistor



, $V = iR$

Node Voltage Method

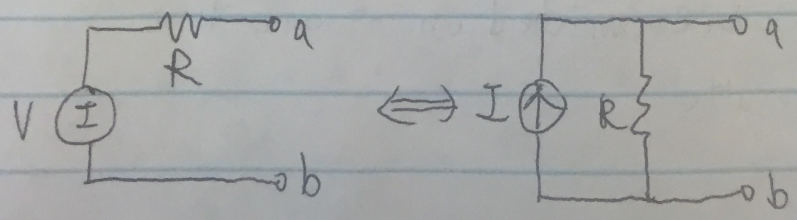
1. Find reference node
2. Mark all the voltages (at other nodes)
3. Apply KCL at each node (except the reference node)

* supernode: a voltage source between 2 essential nodes (apply KCL to the supernode)

Mesh Current Method

1. Identify all the meshes
2. Identify supermesh (2 meshes share a current source)
3. Apply KVL to each mesh.

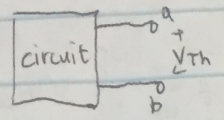
Source Transformation



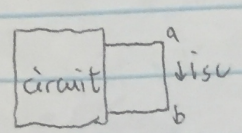
$V = IR$

Thevenin and Norton Equivalent

1. Determine V_{Th}
   - open circuit



2. Determin i_{sc}
   - short circuit

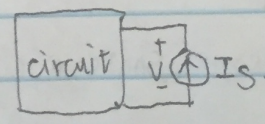


3. Determine R_{Th}

① $R_{Th} = \frac{V_{Th}}{i_{sc}}$

② Turn off all the sources (voltage sources ⇒ short, current sources ⇒ open) and then find the equivalent resistance.

③ For circuits containing <u>only</u> dependent sources, you may obtain uncertain R_{Th}. from ①. To avoid this, apply a test source at the terminals.



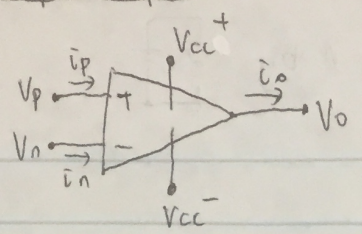
find $V \Rightarrow R_{Th} = \frac{V}{I_s}$

→ test source

Superposition (for resistive circuits)

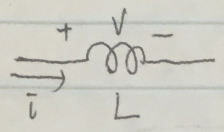
1. Have one source switched on at one time
2. Add the results

Op-Amps



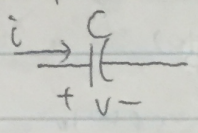
1. virtual short : $V_p = V_n$
2. ∞ input resistance : $i_p = i_n = 0$
3. Saturation : $V_{cc}^- \le V_o \le V_{cc}^+$

Inductors



* $V = L\frac{di}{dt}$
* continuous current $(i(t^+) = i(t^-))$
* $i(t) = \frac{1}{L}\int_{t_0}^{t} v\,d\tau + i(t_0)$
* energy stored : $\frac{1}{2}Li^2$

Capacitors

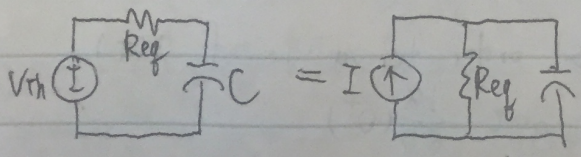


* $i = C\frac{dv}{dt}$
* continuous voltage $(v(t^+) = v(t^-))$
* $v(t) = \frac{1}{C}\int_{t_0}^{t} i\,d\tau + v(t_0)$
* energy stored : $\frac{1}{2}Cv^2$

First-Order circuits (RC, RL)

1. $\tau = RC$ or $\tau = \frac{L}{R}$

Find Thevenin equivalent seen by the capacitor or the inductor.

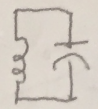


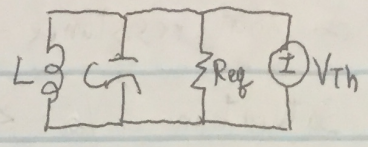
← obtain this form

2. $x(t) = x_\infty + (x(0) - x_\infty)e^{-\frac{t}{\tau}}$
   - natural response : $x(t) = x(0^+)e^{-\frac{t}{\tau}}$, $t > 0$
   - step response : $x(t) = x_\infty - x_\infty e^{-\frac{t}{\tau}}$

* $i_L(0^+) = i_L(0^-)$, $v_C(0^+) = v_C(0^-)$

Second-Order Circuits (RLC)

1. Determine Thevenin equivalent seen by 

   obtain 

2. Find parameters α and ω_0

   $\alpha = \frac{1}{2RC}$, $\omega_0 = \frac{1}{\sqrt{LC}}$

3. Determine the system

   $\alpha^2 - \omega_0^2 > 0$: overdamped $\Rightarrow S_{1,2} = -\alpha \pm \sqrt{\alpha^2 - \omega_0^2}$

   $\alpha^2 - \omega_0^2 = 0$: critically damped $\Rightarrow S = -\alpha$

   $\alpha^2 - \omega_0^2 < 0$: underdamped.

4. Have the equation

   solve this first

   overdamped : $x(t) = A_1 e^{S_1 t} + A_2 e^{S_2 t} + x(\infty)$

   critically damped : $x(t) = D_1 t e^{st} + D_2 e^{st} + x(\infty)$

   underdamped : $x(t) = e^{-\alpha t}(B_1 \cos \omega_d t + B_2 \sin \omega_d t) + x(\infty)$, where

   $$\omega_d = \sqrt{\omega_0^2 - \alpha^2}$$

5. Solve the coefficients

   <i> initial value $x(0) = A_1 + A_2 + x(\infty)$

   $x(0) = D_2 + x(\infty)$

   $x(0) = B_1 + x(\infty)$

   <ii> first-order derivative

   - find the first order derivative of $x(t)$
   - the you can get $\frac{dx}{dt}(0^+)$

     for inductors, $\frac{di_L}{dt}(0^+) = \frac{V_L(0^+)}{L}$

     for capacitors, $\frac{dV_C}{dt}(0^+) = \frac{i_C(0^+)}{C}$