Class Load
Syllabus & tentative schedule outline the workload for this semester. This is a very busy class. Every week will require **AT LEAST 10 HOURS** of outside studying to pass class.

ECE3700 + ECE2280 = Very busy semester – **Organize your time!**

How can you survive??

1. Easiest way to get through school is to actually learn and try to retain what you are asked to learn.
    - Even if you're too busy, don't lose your good study practices. What you "just get by" on today will cost you later.
    - Don't fall for the "I'll never need to know this" trap. Sure, much of what you learn you may not use, but some you will need, either in the current class, or future classes, or maybe sometime in your career. Don't waste time second-guessing the curriculum, It'll still be easier to just do your best to learn and retain.

2. Don't fall for the "traps".
    - Homework answers, Extra problem solutions, Posted solutions, Lecture notes.

3. KEEP UP! Use calendar.

4. Make **"PERMANENT NOTES"** after you've finished a subject and feel that you know it.

REVIEW:

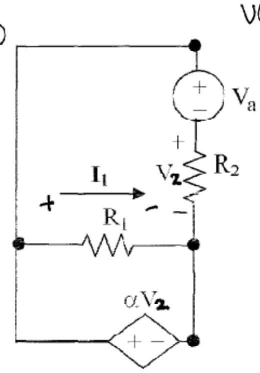
- KVL, KCL, OHM'S LAW, THEVENIN EQUIVALENCE, OPAMPS

a. Derive an expression for I_1. The expression must not contain more than the circuit parameters α, V_a, R_1, and R_2. **(Make sure to eliminate V_2 from the answer) ($\alpha \neq 1$)**

voltage loop: $+\alpha V_2 - V_a - V_2 = 0$

$V_2(\alpha - 1) = V_a$

$V_2 = \frac{V_a}{(\alpha-1)}$

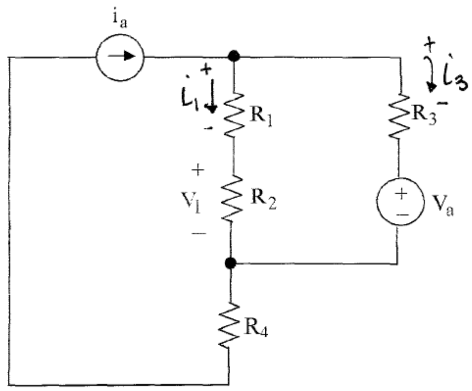


voltage loop: $-I_1R_1 + V_2 + V_a = 0$

$I_1 = \frac{V_2 + V_a}{R_1} = \frac{V_a}{(\alpha-1)R_1} + \frac{V_a(\alpha-1)}{R_1(\alpha-1)}$

$I_1 = \frac{\cancel{V_a} + V_a\alpha - \cancel{V_a}}{(\alpha-1)R_1} = \boxed{\frac{V_a\alpha}{(\alpha-1)R_1}}$

Derive an expression for v_1. The expression must not contain more than the circuit parameters V_a, i_a, R_1, R_2, R_3, and R_4. *(Hint: It is not just a simple voltage divider)*



Ohm's Law: V=I*R

$V_1 = i_1 R_1$

KCL: Summation of currents: $i_a - i_1 - i_3 = 0$ ①

KVL: voltage loop: $+i_1(R_2) + i_1(R_1) - i_3(R_3) - V_a = 0$ ②

From ① $\Rightarrow$ $i_3 = i_a - i_1$ (plugging this into ②)

$i_1(R_1+R_2) - (i_a - i_1)(R_3) - V_a = 0$

$i_1(R_1+R_2+R_3) = i_a R_3 + V_a$

$\therefore \quad i_1 = \dfrac{i_a R_3 + V_a}{R_1+R_2+R_3}$

$V_1 = i_1 R_1 = \boxed{\dfrac{i_a R_3 R_1 + V_a R_1}{R_1+R_2+R_3}}$

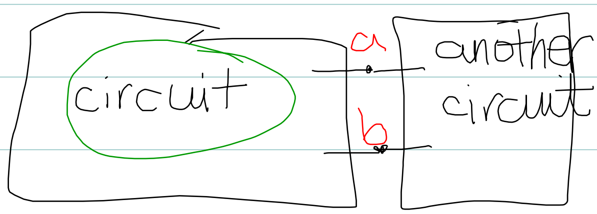
Thevinen Equivalence:

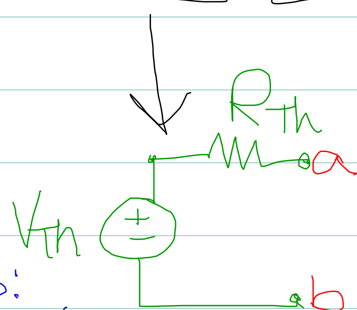
CASE 1: Thevenin Equivalent (circuit with only independent sources)

Step 1. Turn off all independent sources. (This means V=0 (short) and I=0 (open))

Step 2. Rth=equivalent R seen between the two desired nodes a-b.

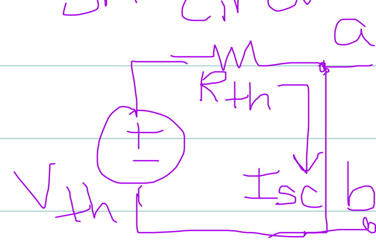
Step 3. Vth= open circuit voltage between a-b.





acts the same

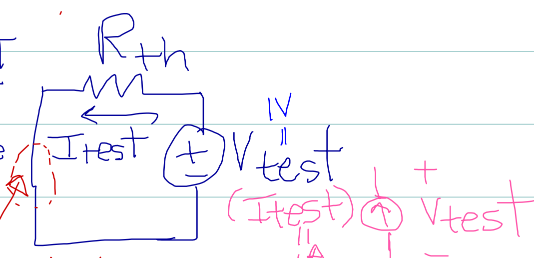
short circuit:



$$R_{th} = \frac{V_{th}}{I_{sc}}$$

Test source:

$$R_{th} = \frac{\overset{1V}{V_{test}}}{\underset{\substack{\uparrow \\ \text{analyze circuit to find}}}{I_{test}}}$$



independent src to zero

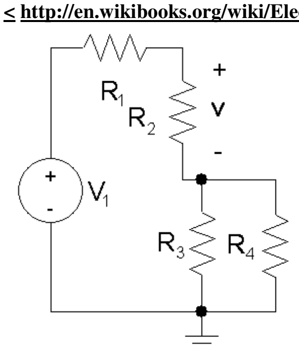
CASE 2: Thevenin Equivalent (circuit with dependent sources)
Step 1. Calculate the open circuit voltage, Vth.
Step 2. Calculate Rth. Use only one of the methods below:

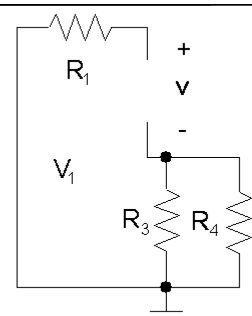
Method 1: TEST SOURCE
(a) Remove all independent sources.
(b) Apply a voltage source *Vtest* between *a-b* and determine the resulting current *Itest*. {OR apply a current source *Itest* between *a-b* and determine the resulting voltage *Vtest*. Using 1V or 1A as the value of the applied test sources allow easy multiplication or division)
(c) Rth=Vtest/Itest

Method 2: SHORT CIRCUIT
(a) Short circuit between a-b and find Isc, short circuit current.
(b) R_{Th} = Vth/*Isc*

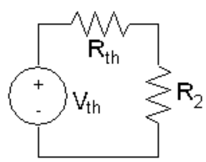
Example, Case 1: (independent sources) Find Thevenin across R2(Removing R2 from the circuit).
< http://en.wikibooks.org/wiki/Electronics/Thevenin/Norton_Equivalents>

independent sources.
hort) and I=0 (open))
R.

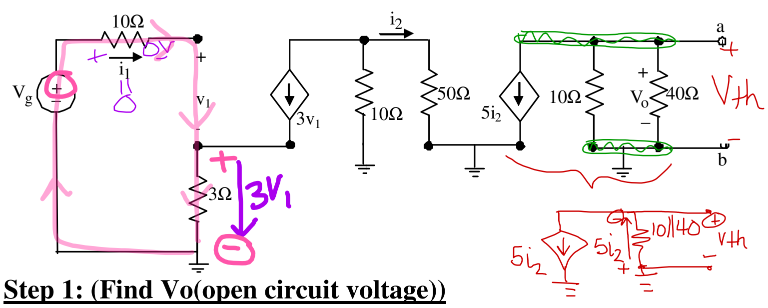




Step 2 and Step 3:
$$R_{th} = R_1 + R_3||R_4$$
$$V_{th} = V_1$$



Example Case 2:
Find Thevenin between a-b.



Step 1: (Find Vo(open circuit voltage))

Vo=-5i2(10||40)=-5i2(10)(40)/50 = -40i2

i2=-3v1(10)/60 = -1/2v1

Vg-10i1-v1-3v1(3)=0 (i1=0) => 10v1=Vg

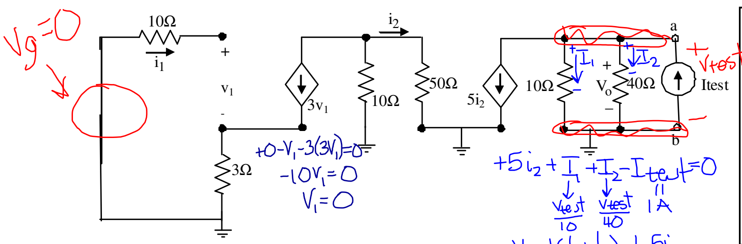
Vo=-40(-1/2)(Vg/10) = +2Vg=Vth

Step 2:

Method 1: TEST SOURCE

(a) Remove all independent sources.

(b) Apply a test source (Itest in this case). Analyze circuit for Vtest=Vo in this case.



Vo=Vtest = (10||40)*(Itest-5i2)

i1=0

v1=-3v1(3) => v1+9v1=0=> v1(10)=0 => v1=0

i2=0

Vtest = 8Itest

Rth = 8Itest/Itest = 8ohm

$+5i_2 + I_1 + I_2 - I_{test} = 0$

$I_1 = \frac{V_{test}}{10}$, $I_2 = \frac{V_{test}}{40}$, $I_{test} = 1A$

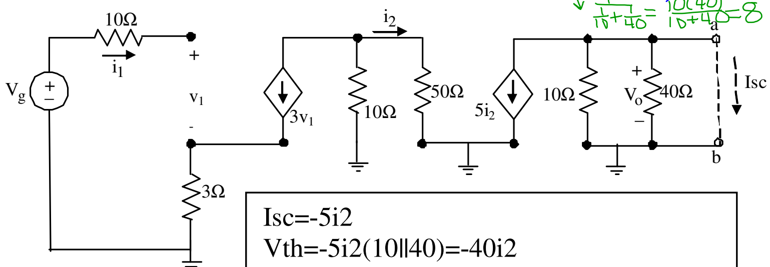
$V_{test}\left(\frac{1}{10}+\frac{1}{40}\right) = 1 - 5i_2$ Itest

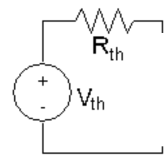
$V_{test} = (10||40)(1-5i_2)$

$\frac{1}{\frac{1}{10}+\frac{1}{40}} = \frac{10(40)}{10+40} = 8$

Step 2:

Method 2: SHORT CIRCUIT





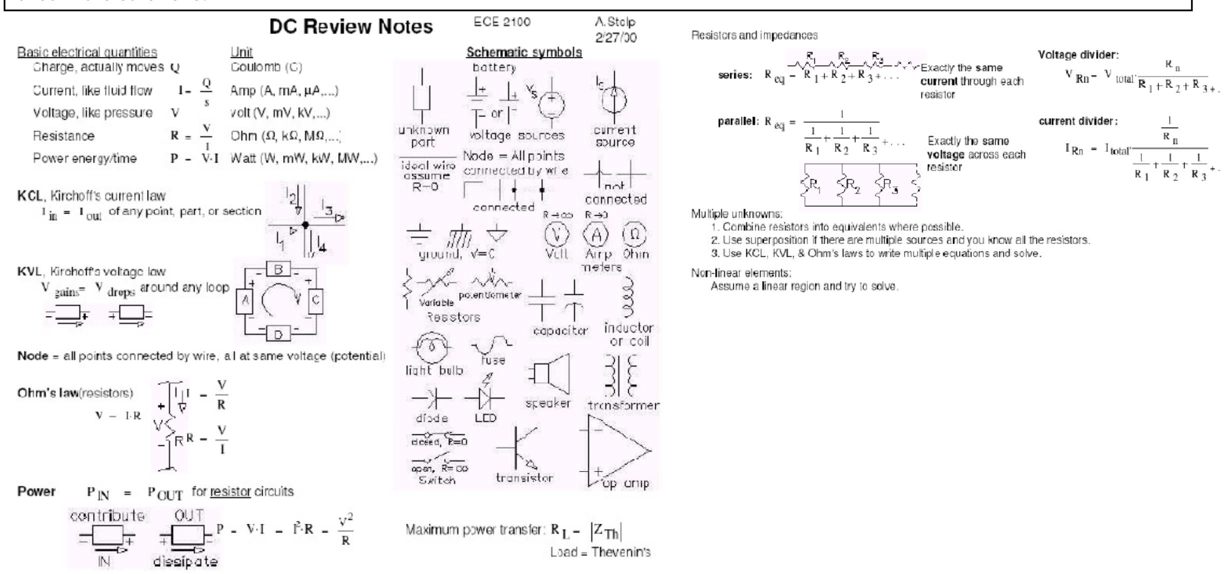
Isc=-5i2

Vth=-5i2(10||40)=-40i2

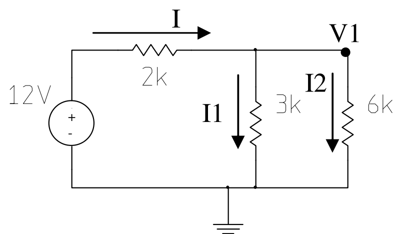
Rth = Vth/Isc=-40i2/-5i2 = 8ohm

SAME

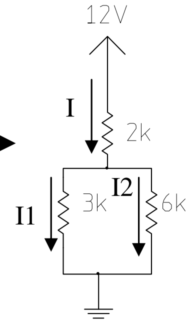
Note: Use of the Isc is sometimes easier than the test source. Suggest trying that method first. Both method's can be used to "check" the other one.



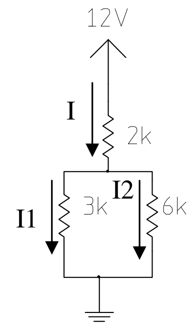
Example #3



Same as $\Longrightarrow$



Solve for I, I1, I2, and V1: $I = \dfrac{12V}{2k + 3k\|6k} = \dfrac{12}{2k + \left(\frac{3k(6k)}{3k+6k}\right)} = \dfrac{12}{2k+2k} = 3mA$



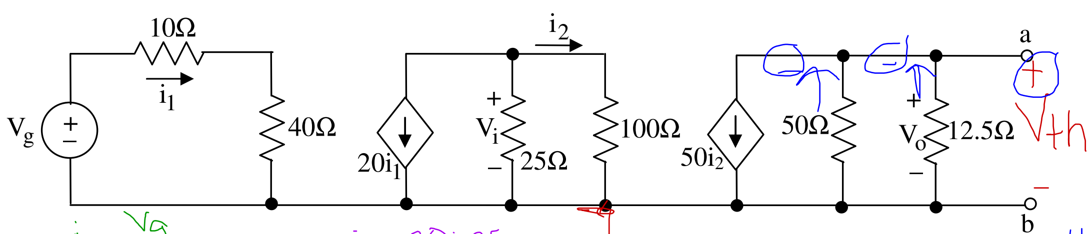
$I1 = \frac{V1}{3k}; I2 = \frac{V1}{6k}$

$I = I1 + I2 = V1\left(\frac{1}{3k} + \frac{1}{6k}\right) = V1\left(\frac{3k}{6k}\right) = V1\left(\frac{1}{2k}\right) \Rightarrow V1 = I \cdot 2k = 3m(2k) = 6V$

$I1 = \frac{6}{3k} = 2mA; I2 = \frac{6}{6k} = 1mA$

Example #4

Given V_g=6.25mV, find V_o. Find the Thevenin equivalent between terminals a-b.



$i_1 = \frac{V_g}{50}$

$i_2 = \frac{-20 i_1 \cdot 25}{125}$

0V

$V_{th} = -50 i_2 (50 \| 12.5)$

$V_{th} = V_o \rightarrow$ Therefore find V_o:

$$V_o = \underbrace{(50\Omega \,||\, 12.5\Omega)}_{\frac{50\cdot 12.5}{12.5+50} = 10\Omega} \cdot (-50 i_2) = -500\, i_2$$ unknown – find eq. for i_2

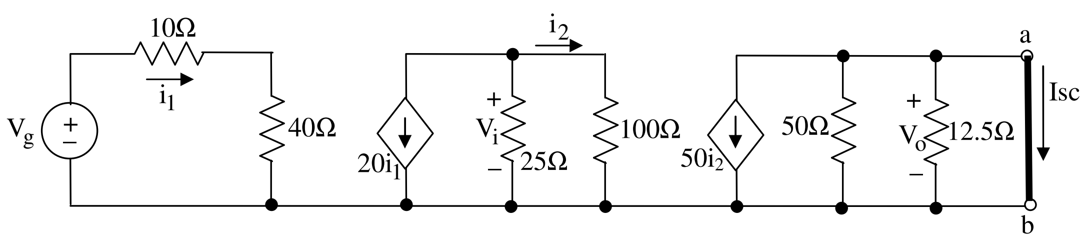
$$\Rightarrow i_2 = \frac{V_i}{100} = \frac{-20 i_1 \cdot (25||100)}{100} = \frac{-20 i_1}{100} \cdot \frac{25\cdot 100}{100+25} = -4 i_1$$ – unknown find new eq

$$\Rightarrow i_1 = V_g/(10+40) = \frac{6.25m}{50} = .125m$$ – No unknowns plug into previous equations

$$i_2 = -4 i_1 = -4(.125m) = -.5m$$

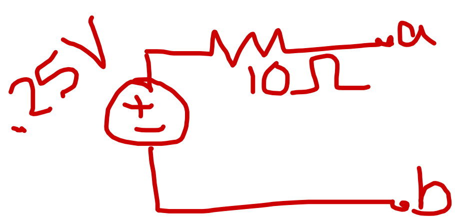
$$V_{th} = V_o = -500 i_2 = +500(+.5) = \boxed{.250V}$$

$$R_{th} = \frac{V_{th}}{i_{sc}}$$, where i_{sc} is the short circuited current =>



From the analysis for Vth (above). Vth=-500i2
Isc=-50i2 so

Rth=-500i2/-50i2=$\boxed{\text{10ohm}}$
(note that for this circuit configuration, it appears that the output R (Rth) that the "top" of the dependent current source looks like an "open" so that the equivalent R is 50||12.5=10ohm).



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Homework #4 Examples

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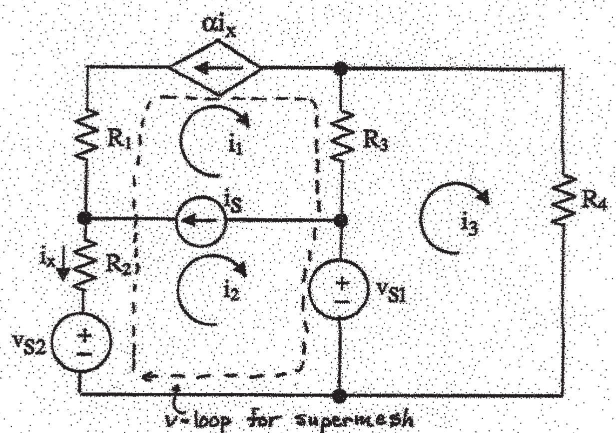
3.



For the circuit shown, write three independent equations for the three mesh currents i_1, i_2, and i_3. The quantity i_x must not appear in the equations.

sol'n: First, write i_x in terms of mesh currents.

$i_x = -i_2$ (use mesh currents only)

Now do v-loops for mesh currents.

we have current source between loops for i_1 and i_2.

∴ we have supermesh loop around outside of i_1 and i_2 loops (that avoids having to define v for i_s).

don't use i_x here!

supermesh v-loop: $+v_{S2} - i_2 R_2 - i_1 R_1 -$ stop! current src <u>not allowed</u>

we must not need this v-loop. Indeed, we have a current src on the outside edge, giving us $\boxed{i_1 = -\alpha(\underbrace{-i_2}_{=\,i_x})}$

we must also have a current eq'n for i_s source to complete super mesh:

$$\boxed{i_s = i_1 - i_2}$$

flows against i_s so is minus

Normal v-loop for i_3:

$$\boxed{\begin{aligned}+v_{S1} - i_3 R_3 &- i_3 R_4 = 0V \\ + i_1 R_3 &\end{aligned}}$$

Question only requires 3 eq'ns we <u>could</u> solve, but we <u>don't have to solve them</u>.

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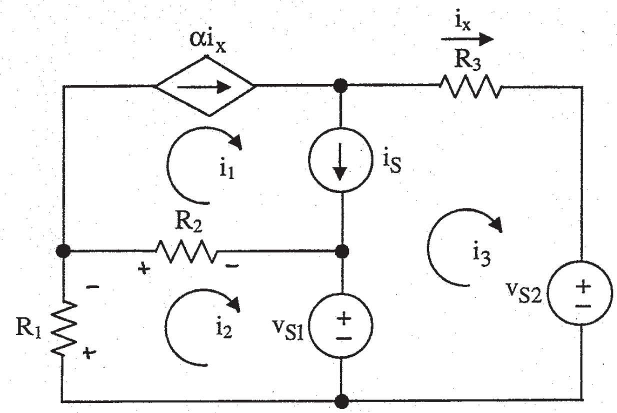
1. c. (20 points)



For the circuit shown, write three independent equations for the three mesh currents i_1, i_2, and i_3. The quantity i_x must not appear in the equations.

soln: αi_x dependent src in terms of i_1, i_2, i_3:

$\alpha i_x = i_1$, $i_x = i_3$ so $\boxed{\alpha i_3 = i_1}$

supermesh for i_1 and i_3 loops:

$\boxed{i_s = i_1 - i_3}$

outer loop for i_1 and i_3? No, because of αi_x src.

Mesh eq'n for i_2:

$\boxed{-i_2 R_1 - i_2 R_2 - v_{s1} = 0V}$

Homework #4 Examples

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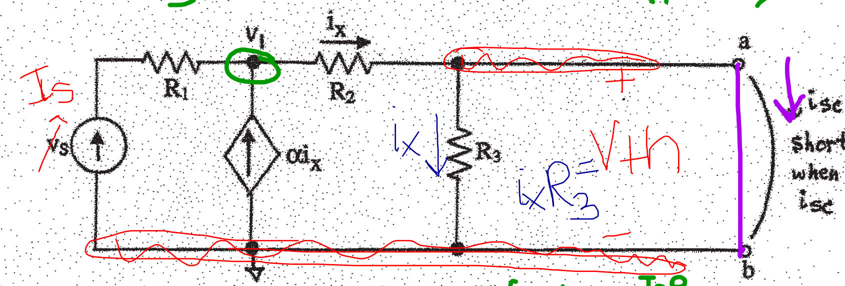
4.

$$-I_s - \alpha i_x + i_x = 0 \rightarrow i_x = \frac{I_s}{(1-\alpha)}$$



$$I_{sc} = \frac{I_s}{(1-\alpha)}$$

$$V_{th} = \frac{I_s R_3}{(1-\alpha)}$$

Find the Thevenin's equivalent circuit at terminals a-b. i_x must not appear in your solution. **Hint:** Use the node voltage method. **Note:** $\alpha > 0$.

$$R_{th} = \frac{V_{th}}{I_{s1}} = R_3$$

soln: Assuming v_s is <u>current src</u>:

$V_{Thev} = V_{a,b}$ open circuit

use node-voltage method to find v_1:

$$-\cancel{v_s}\,{-I_s} - \alpha \underbrace{\boxed{\frac{v_1}{R_2+R_3}}}_{= i_x} + \frac{v_1}{R_2+R_3} = 0A$$

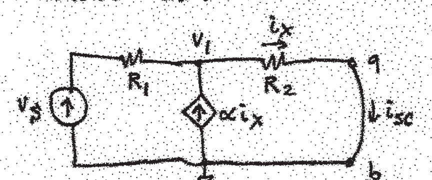
or $\quad v_1 \dfrac{1-\alpha}{R_2+R_3} = I_s$

$$v_1 = I_s \frac{R_2+R_3}{1-\alpha}$$

$$V_{Thev} = v_1 \cdot \frac{R_3}{R_2+R_3} = v_s \frac{R_3}{1-\alpha} \qquad \text{v-divider}$$

Now short a,b terminals and find i_{sc} flowing from a to b.

Note that R_3 will carry no current; it all flows thru the short. ∴ we may ignore R_3.



Use node voltage to find v_1.

$$-v_s - \alpha \underbrace{\boxed{\frac{v_1}{R_2}}}_{= i_x} + \frac{v_1}{R_2} = 0A$$

$$v_1 = v_s \frac{R_2}{1-\alpha}$$

Now, $\quad i_{sc} = i_x = \dfrac{v_1}{R_2} = \dfrac{v_s}{1-\alpha}$

$$R_{Thev} = V_{Thev} / i_{sc} = R_3$$

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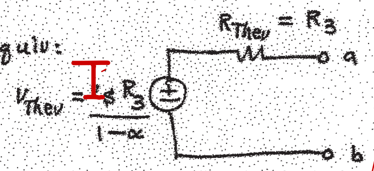
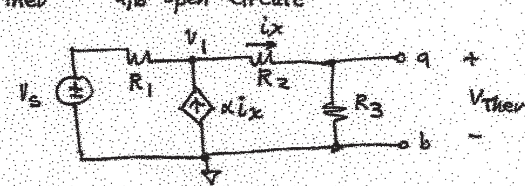
4. cont.

Thevenin equiv:



Assuming v_s is voltage src $\pm$ v_s:

$V_{Thev} = V_{a,b}$ open circuit



Use node-voltage method to find v_1:

$$\frac{v_1 - v_s}{R_1} - \alpha \underbrace{\boxed{\frac{v_1}{R_2+R_3}}}_{= i_x} + \frac{v_1}{R_2+R_3} = 0A$$

$$v_1 \left(\frac{1}{R_1} + \frac{1-\alpha}{R_2+R_3} \right) = \frac{v_s}{R_1}$$

mult both sides by R_1 and re-arrange:

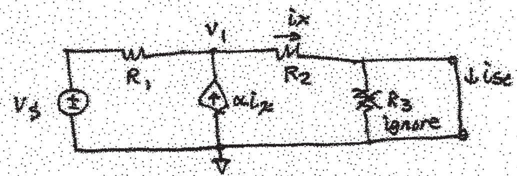
$$v_1 = \frac{v_s}{1 + \frac{(1-\alpha) R_1}{R_2+R_3}}$$

$$V_{Thev} = v_1 \cdot \frac{R_3}{R_2+R_3} = \frac{v_s R_3}{\left(1 + \frac{(1-\alpha) R_1}{R_2+R_3}\right)(R_2+R_3)}$$

$$V_{Thev} = \frac{v_s R_3}{R_2+R_3+(1-\alpha)R_1}$$

Now short a,b terminals and find i_{sc} flowing from a to b. Note that R_3 will be bypassed. All current will flow thru short. ∴ we may ignore R_3.

4. cont.



use node-voltage to find v_1:

$$\frac{v_1 - v_s}{R_1} - \alpha \underbrace{\boxed{\frac{v_1}{R_2}}}_{= i_x} + \frac{v_1}{R_2} = 0A$$

$$v_1 \left(\frac{1}{R_1} + \frac{1-\alpha}{R_2} \right) = \frac{v_s}{R_1}$$

or $$v_1 = \frac{v_s}{1 + \frac{(1-\alpha) R_1}{R_2}}$$

$$i_{sc} = i_x = \frac{v_1}{R_2} = \frac{v_s}{R_2 + (1-\alpha) R_1}$$

$$R_{The} = \frac{v_{Thev}}{i_{sc}} = \frac{R_3}{R_2 + R_3 + (1-\alpha) R_1} \cdot R_2 + (1-\alpha) R_1$$

$$R_{Thev} = R_3 \| [R_2 + (1-\alpha) R_1]$$

Thevenin equiv: