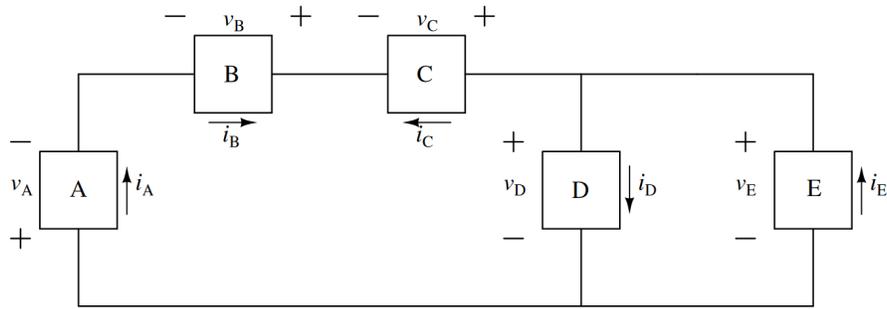
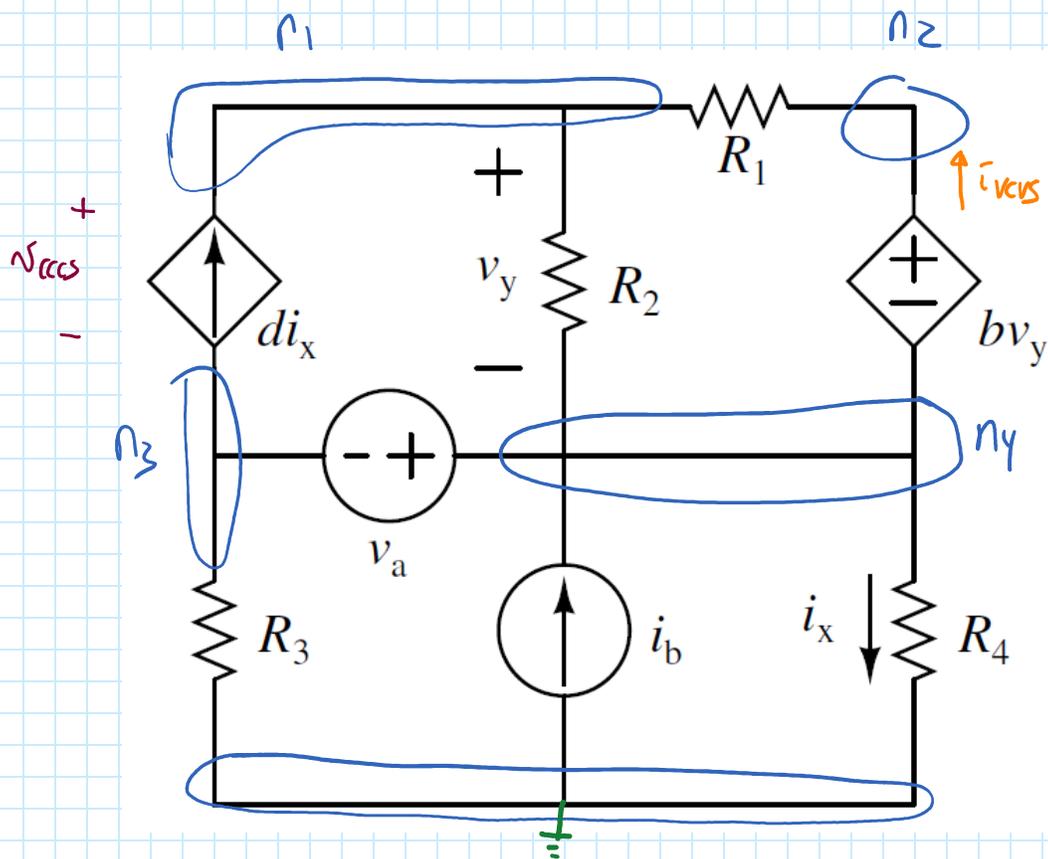


Name	Variable	Units	Equation
voltage	v	V	$\frac{dv}{dq}, Ri$
charge	q	C	N/R
power	p	W	$v i$
conductance	G	S	N/R
resistance	R	Ω	$\frac{PL}{A}, \frac{v}{i}$
work/energy	w	J	N/R
current	i	A	$\frac{dq}{dt}$

2



Element	Conv.	Voltage v , V	Current i , A	Power Absorbed p_{abs} , W
A	P	20	4	80
B	A	38	4	-152
C	P	-8	-4	32
D	P	10	1	10
E	A	10	-3	30



	n_1	n_2	n_3	n_y	UNK
VLL, LL	v_{n_1}	v_{n_2}	v_{n_3}	v_{n_y}	$v_{n_1}, v_{n_2}, v_{n_3}, v_{n_y}, i_x, v_y$
SL	v_{n_3}, v_a, v_y	$v_{n_3} + v_a + b v_y$	v_{n_3}	$v_{n_3} + v_a$	v_{n_3}, i_x, v_y
RSL	$R_1 i_x + v_y$	$R_1 i_x + b v_y$	$R_3 i_x - v_a$	$R_4 i_x$	i_x, v_y

$$\text{KCL, } n_1: -d i_x + \frac{(v_{n_1} - v_{n_2})}{R_1} + \frac{(v_{n_1} - v_{n_y})}{R_2} = 0$$

$$\text{KCL, } n_{23y}: d i_x + \frac{(v_{n_2} - v_{n_1})}{R_1} + \frac{(v_{n_y} - v_{n_1})}{R_2} + \frac{(v_{n_2} - 0)}{R_3} - i_b + \frac{(v_{n_y} - 0)}{R_4} = 0$$

$$\text{LALT: KCL, } n_{123y}: \frac{(v_{n_3} - 0)}{R_3} - i_b + \frac{(v_{n_y} - 0)}{R_4} = 0$$

$$\text{FOR VLL, LL, SL: MEAS, } i_x: i_x = \frac{v_{n_y} - 0}{R_4}$$

$$P_{abs, R_1} = \frac{(v_{n_1} - v_{n_2})^2}{R_1}$$

$$\text{FOR VLL, SL: SRC, } v_a: v_a = v_{n_y} - v_{n_3}$$

$$\text{SRC, } v_{cvcs}: b v_y = v_{n_2} - v_{n_y}$$

$$\text{MEAS, } v_y: v_y = v_{n_1} - v_{n_y}$$

$$P_{del, cvcs} = (v_{n_1} - v_{n_3}) d i_x$$

$$P_{del, cvcs} = b v_y i_{cvcs}$$

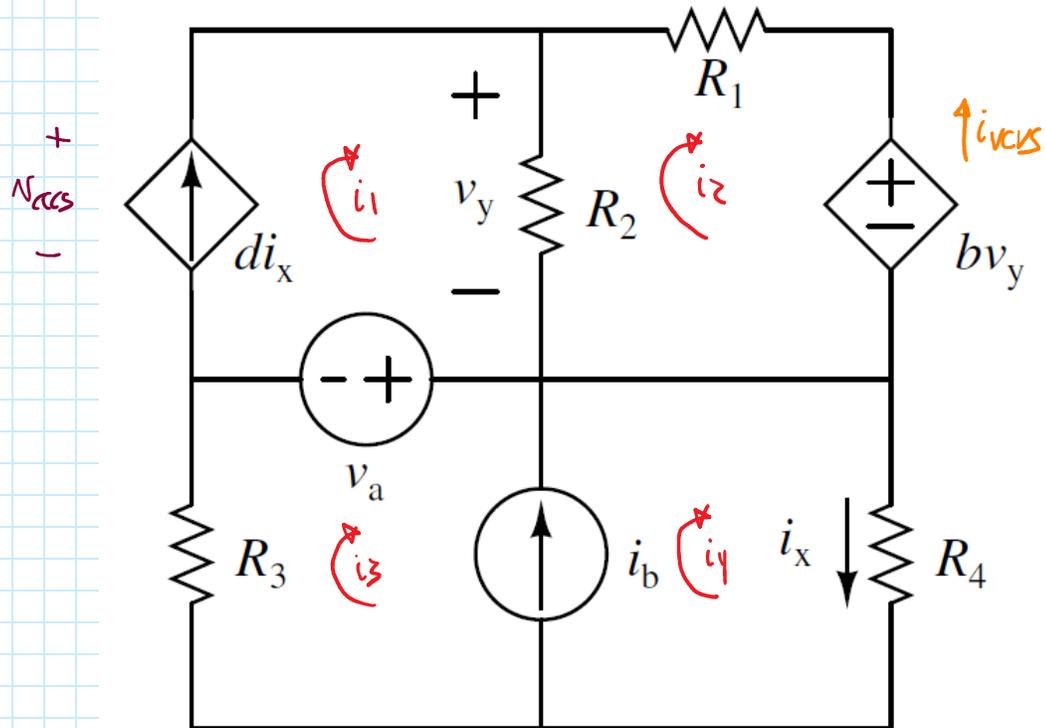
$$\text{KCL, } n_2: \frac{v_{n_2} - v_{n_1}}{R_1} - i_{cvcs} = 0$$

$$i_{cvcs} = \frac{(v_{n_2} - v_{n_1})}{R_1}$$

or

$$\text{KCL, } n_{3y} = \text{emv...}$$

4 MCM



$$KV_1, l_2: R_2(i_2 - i_1) + R_1 i_2 + b v_y = 0$$

$$KV_1, s_{34}: R_3 i_3 - v_a + R_4 i_4 = 0$$

$$SRC, i_b: i_b = i_4 - i_3$$

$$SRC, ccs: di_x = i_1$$

$$MEAS, i_x: i_x = i_4$$

$$MEAS, v_y: v_y = R_2(i_1 - i_2)$$

$$p_{abs, R_1} = i_2^2 R_1$$

$$p_{del, ccs} = di_x v_{ccs}$$

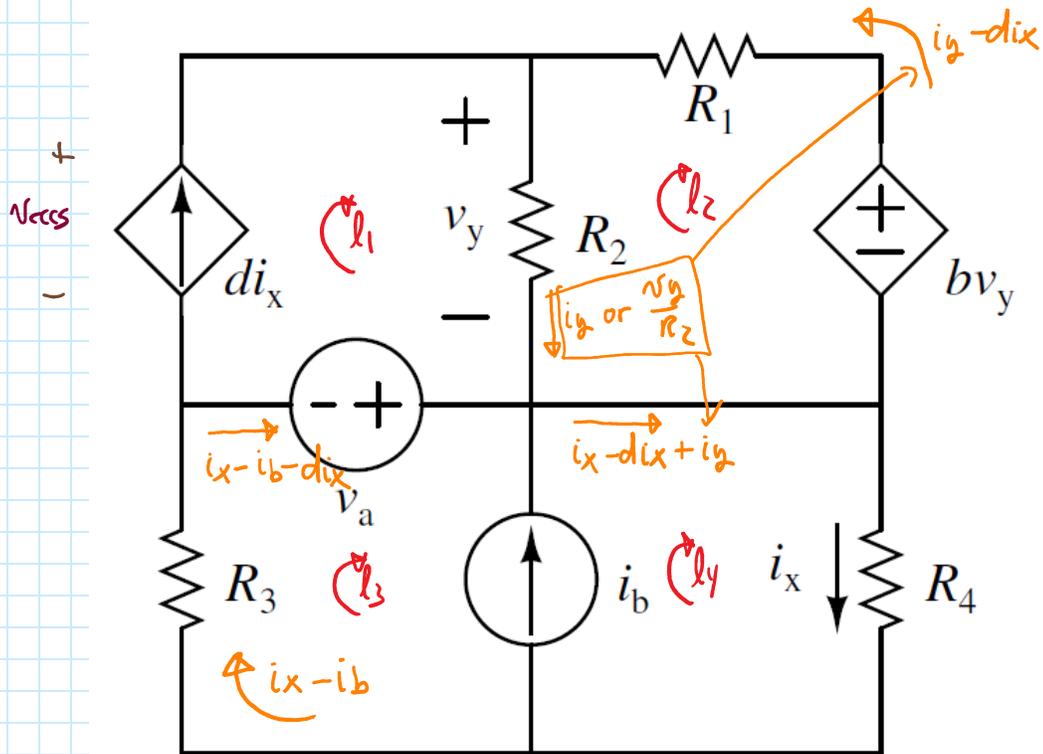
$$KV_4, l_1: -v_{ccs} + R_2(i_1 - i_2) + v_a = 0$$

$$v_{ccs} = R_2(i_1 - i_2) + v_a$$

$$p_{del, vcs} = b v_y i_{vcs}$$

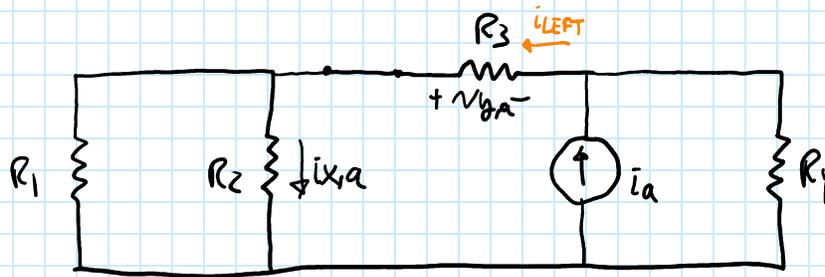
$$= -b v_y i_2$$

4 BCM



UNK: i_x, i_b, v_y or i_x, v_y
 KVL, l_2 : $-R_2 i_2 - R_1 (i_2 - di_x) + bv_y = 0$ or $-v_y - R_1 (\frac{v_y}{R_2} - di_x) + bv_y$
 KVL, l_3 : $R_3 (i_x - i_b) - v_a + R_4 i_x = 0$
 IF NEEDED: $v_y = R_2 i_2$
 Pabs, R_1 : $(i_2 - di_x)^2 R_1$
 Pdel, ccs: $v_{ccs} di_x$ KVL, l_1 : $-v_{ccs} + v_y + v_a = 0$ $v_{ccs} = v_y + v_a$
 Pdel, vcs: $bv_y (i_2 - di_x)$

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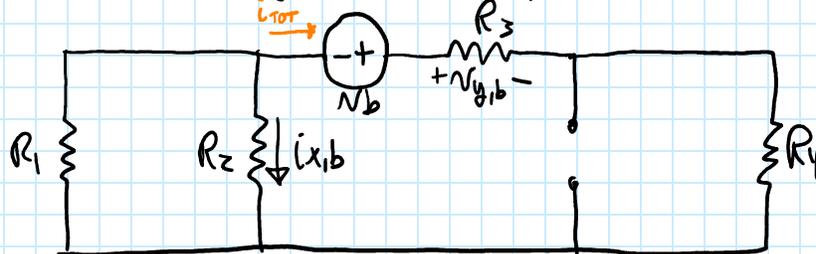
 i_a :

$$R_{12} = R_1 \parallel R_2 \quad R_{123} = R_{12} + R_3 \quad R_{1234} = R_{123} \parallel R_4$$

$$i_{\text{LEFT}} = i_a \frac{R_{1234}}{R_{123}} = \frac{i_a R_4}{R_{123} + R_4}$$

$$v_{ga} = -R_3 i_{\text{LEFT}}$$

$$i_{x_a} i_{\text{LEFT}} \frac{R_{12}}{R_2} = i_{\text{LEFT}} \frac{R_1}{R_2 + R_1}$$

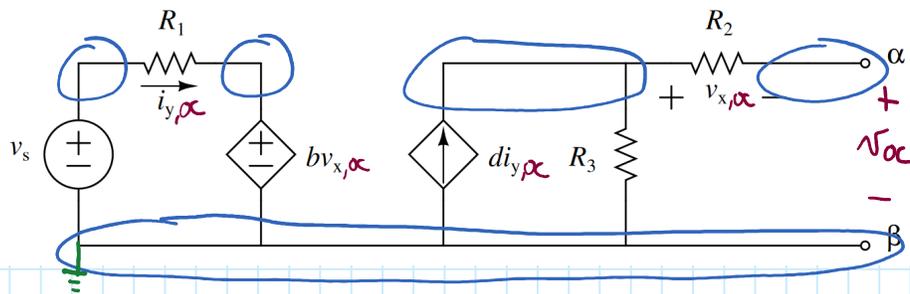
 v_b :

$$R_{12} = R_1 \parallel R_2 \quad R_{124} = R_{12} + R_4 \quad R_{1234} = R_{124} + R_3$$

$$v_{gib} = \frac{v_b R_3}{R_{1234}}$$

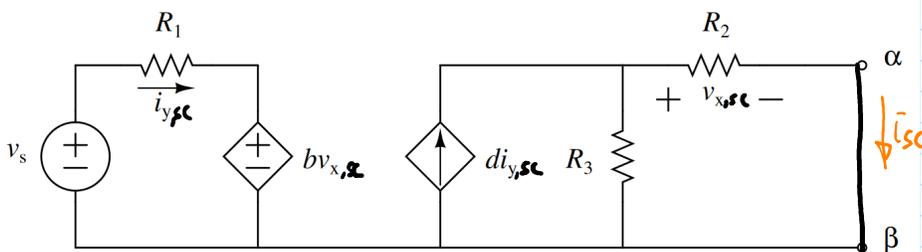
$$i_{\text{TOT}} = \frac{v_b}{R_{1234}}$$

$$i_{x_b} = -i_{\text{TOT}} \frac{R_{12}}{R_2} = \frac{-i_{\text{TOT}} R_1}{R_2 + R_1}$$



$$v_{x,oc} = 0 \quad i_{y,oc} = \frac{v_s - 0}{R_1} = \frac{v_s}{R_1}$$

$$V_{oc} = d i_{y,oc} R_3 = \frac{d R_3 v_s}{R_1}$$



$$i_{sc} = d i_{y,sc} \frac{R_2 \parallel R_3}{R_2} \quad v_{x,sc} = i_{sc} R_2 = d i_{y,sc} (R_2 \parallel R_3)$$

$$i_{y,sc} = \frac{v_s - b v_{x,sc}}{R_1} = \frac{v_s - b d i_{y,sc} (R_2 \parallel R_3)}{R_1}$$

$$i_{y,sc} (R_1 + d b (R_2 \parallel R_3)) = v_s$$

$$i_{y,sc} = \frac{v_s}{R_1 + d b (R_2 \parallel R_3)}$$

$$i_{sc} = \frac{d (R_2 \parallel R_3)}{R_2} \frac{v_s}{R_1 + d b (R_2 \parallel R_3)} = \frac{d R_3 v_s}{R_1 R_2 + R_1 R_3 + d b R_2 R_3}$$

$$R_{Th} = \frac{V_{oc}}{i_{sc}} = \frac{\frac{d R_3 v_s}{R_1}}{\frac{d R_3 v_s}{R_1 R_2 + R_1 R_3 + d b R_2 R_3}} = \frac{R_2 R_3}{R_1} \frac{R_1 + d b (R_2 \parallel R_3)}{R_2 \parallel R_3} = \frac{R_1 R_2 + R_1 R_3 + d b R_2 R_3}{R_1}$$

(check $d=0$ means dead circuit w/ $R_2 + R_3$)

$$R_{Th} = \frac{R_2 R_3}{R_1} \frac{R_1}{R_2 \parallel R_3} = R_2 R_3 \frac{(R_2 + R_3)}{R_2 R_3} = R_2 + R_3 \checkmark$$



$$R_L = R_{Th}$$

$$P_{abs} = \frac{V_{oc}^2}{4 R_{Th}} = \frac{I_{sc}^2 R_{Th}}{4}$$