I skipped the rest of Chp 2

3-1 Node-Voltage Analysis p74

from 2-3, circuit behavior is based on constraints of 2 types

1) connection constraints Kirchhoff's Laws
2) Device constraints, element i-v relationships

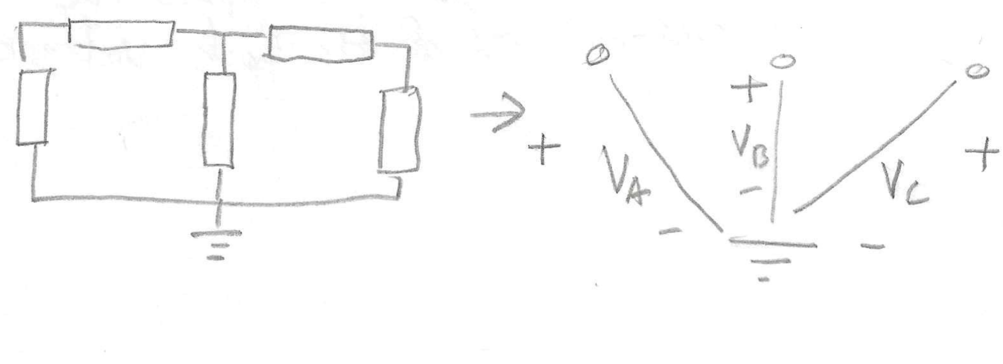
→ A circuit with 6 devices gives us 12 equations with 12 unknowns

We want to reduce the number of equations that must be solved simultaneously

→ Using node voltages instead of element voltages as circuit variables can reduce the number of equations that must be treated simultaneously

→ To define a set of node voltages, we first select a reference node.

Node voltages: voltages between the remaining nodes and the selected reference node



If the Kth two-terminal element is connected between nodes X and Y, then the element voltage can be expressed in terms of the two node voltages as

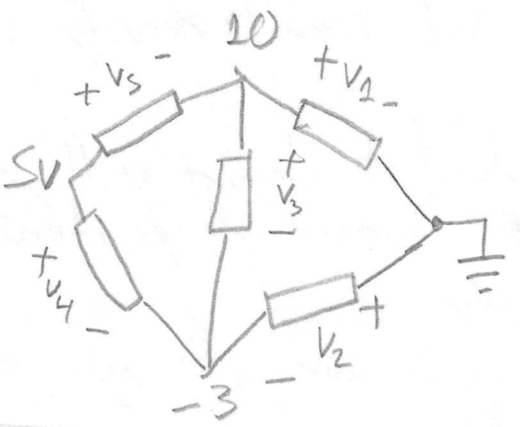
$$v_K = v_X - v_Y \qquad (3-1)$$

where X is the node connected to the positive reference for element voltage v_K

if $v_Y = 0 \rightarrow v_K = v_X$

if $v_X = 0 \rightarrow v_K = -v_Y$

Voltage across an element can be expressed as the difference of two node voltages, one may be zero



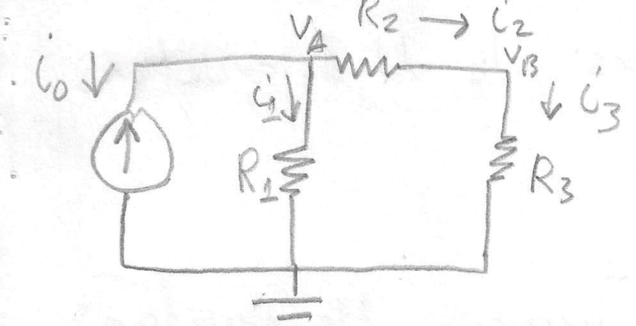
$v_S = -5$
$v_4 = 8$
$v_3 = 13$
$v_2 = 3$
$v_1 = 10$

Formulating Node-Voltage Equations

p 75

circuit description using node voltages

→ use node analysis to express the element voltages in terms of the node voltages



KCL

A: $-i_0 - i_1 - i_2 = 0$

B: $i_2 - i_3 \quad = 0$ (3-2)

3-5 Use Node analysis, So Look at Node A

Then $i_1 = \dfrac{V_A}{R_1}$

$i_2 = \frac{1}{R_2}(V_A - V_B)$ (3-3)

$i_3 = \dfrac{V_B}{R_3}$, $i_0 = -i_s$

We have 4 i's and 2 node voltages, substitute device constraints into KCL connection constraints gets

A: $i_s - \dfrac{V_A}{R_1} - \dfrac{1}{R_2}(V_A - V_B) = 0$

B: $\dfrac{1}{R_2}(V_A - V_B) - \dfrac{V_B}{R_3} = 0$

rewrite

A: $V_A\left(\dfrac{1}{R_1} + \frac{1}{R_2}\right) - V_B\left(\frac{1}{R_2}\right) = i_2$

(3-4)

$-V_A\dfrac{1}{R_2} + V_B\left(\dfrac{1}{R_2} + \frac{1}{R_3}\right) = 0$

We have eleminated the currents, we have reduced the circuit description to two linear equations. We used KCL, and implicitly used KVL

[4 Step Process on p76]

1.) Pick a reference, then Identify Node Voltages
2) KCL at nodes
3) i-v relationships of elements to express i in terms of V
4.) insert (3) Into KCL

(14) We went from $2E$ equations to $N-1$ equations
↑
elements

→ We have several examples of arranging the equations as a matrix arrangement, which is great for organization p77 – p78

$$i = \frac{1}{R}(V_A - 0)$$

$$i = \frac{1}{R}(V_A - V_B)$$

The pattern for node equation follows from these observations.
The sum of the currents leaving any node A via resistance is

1.) V_A times the sum of conductances connected to node A

2.) minus V_B times the sum of conductances connected between nodes A and B

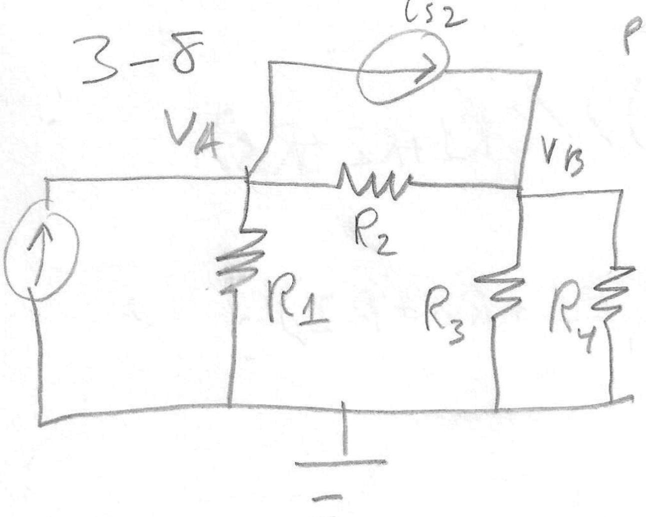
3.) minus similar terms for all other nodes connected to node A by conductances

KCL, sum of currents leaving node A via Rs plus sum of currents directed away from node A by ind. current sources must equal zero

→ We can write node-voltage equations by inspection
[No KCL constraints, or element equations, or labeling currents]

p79 example

3-8 p79



Start w/ A, sum of conductances, G_1, connected to A

minus V_B (conductance between A and B)

minus currents into A

$$\rightarrow \left(R_1^{-1} + R_2^{-1}\right) v_A - \left(R_2^{-1}\right) v_B - i_{s1} + i_{s2} = 0$$

$$B \rightarrow \left(R_2^{-} + R_3^{-} + R_4^{-}\right) V_B - \left(R_2^{-1}\right) V_A - i_{s2} = 0$$

So we have

$$\left(R_1^{-} + R_2^{-}\right) v_A - \left(R_2^{-}\right) v_B = i_{s1} - i_{s2}$$

$$-\left(R_2^{-}\right) v_A + \left(R_2^{-} + R_3^{-} + R_4^{-}\right) v_B = i_{s2}$$

→ Symmetrical matrix

Solving Linear Algebraic Equations p80 - p81

In MatLab, to solve

$$\left(R_1^{-} + R_2^{-}\right) v_A - R_2^{-} v_B = i_s$$

$$-R_2^{-} v_A + \left(R_2^{-} + R_3^{-}\right) v_B = 0$$

First, define symbolic parameters

```
syms R1 R2 R3 iS real
A=[(1/R1 + 1/R2) -1/R2; -1/R2 (1/R2 + 1/R3)];
B=[iS; 0];
X=A\B;
```

x(1) = (R1 * iS * (R2+R3))/(R1+R2+R3)
vA = x(1)
x(2) = (R1 * R3 * iS)/(R1+R2+R3)
vB = x(2)

now we have

$V_1 = V_A \quad V_2 = V_A - V_B \quad V_3 = V_B$ Do the MatLab

$i_1 = \frac{V_A}{R_1} \quad i_2 = \frac{V_A - V_B}{R_2} \quad i_3 = \frac{V_B}{R_3}$

Node Analysis w/ Voltage Sources p84

→ Adding voltage sources to circuits modifies node analysis procedures because current thru a voltage source is not directly related to the voltage accross it

Method 1 Source transformation

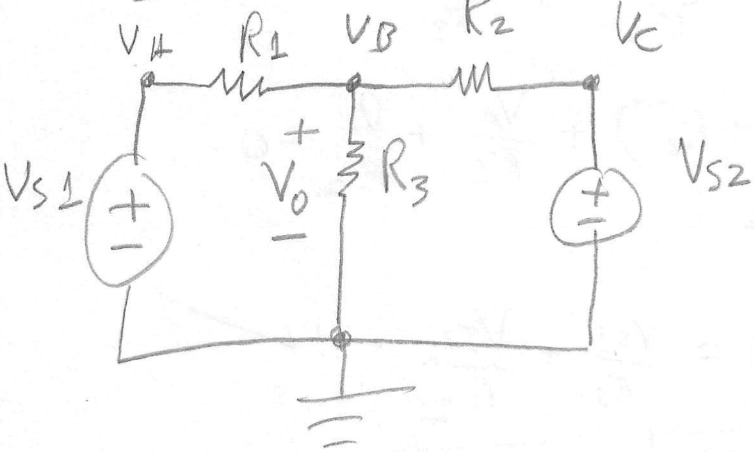
Method 2, don't need a resistor in series
make node B the reference → $V_A = V_S$, we know voltage A
N-2 remaining equations, V_A is known

Method 3: A or B cant be reference, V_s has no R in series → Combine A and B into Super Node
N-3 node equations and 1 supernode equation

[Do all the examples for these methods and PSPICE Later] p85-91

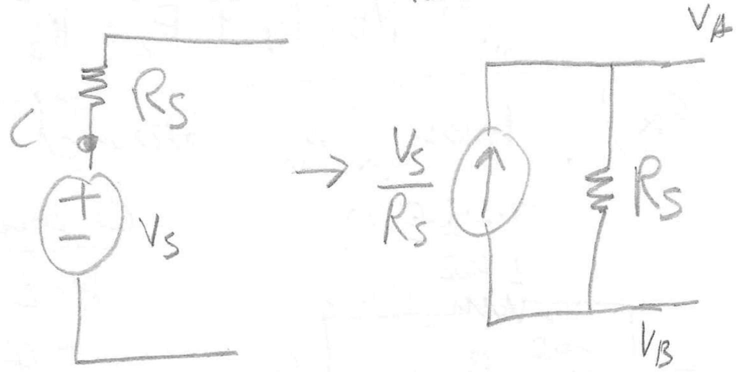
Examples for Node Analysis of Voltage Sources

3-14

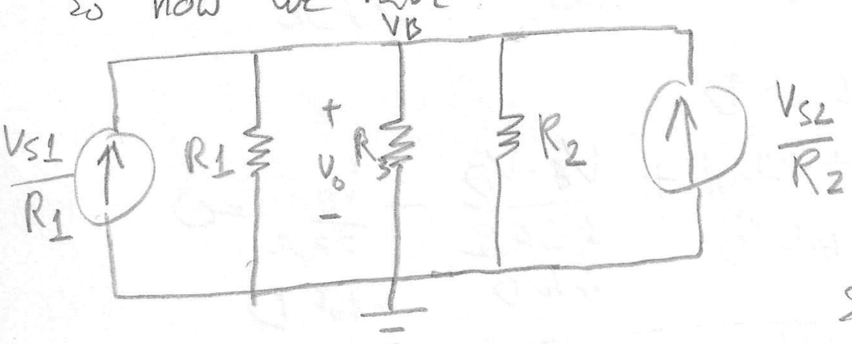


Use node-voltage analysis to find V_o in 3-14

→ use method 1 source transformation



So now we have



So from observation

$$0 = V_B\left(R_1^{-1} + R_2^{-1} + R_3^{-1}\right) - \frac{V_{s1}}{R_1} - \frac{V_{s2}}{R_2}$$

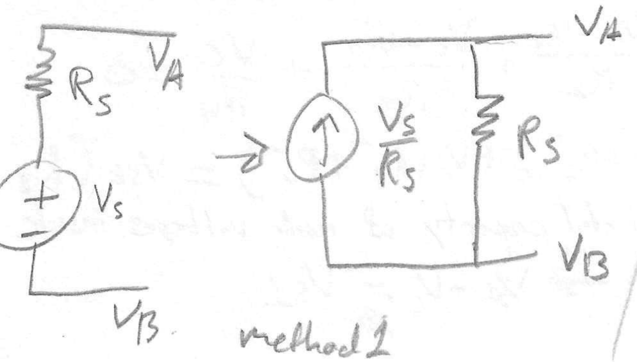
$$V_B = V_o$$

So
$$V_o = \frac{\frac{V_{s1}}{R_1} + \frac{V_{s2}}{R_2}}{\left(R_1^{-1} + R_2^{-1} + R_3^{-1}\right)}$$

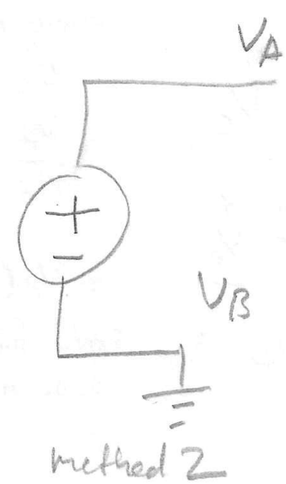
---

method 2, make B the reference

Recall the Methods

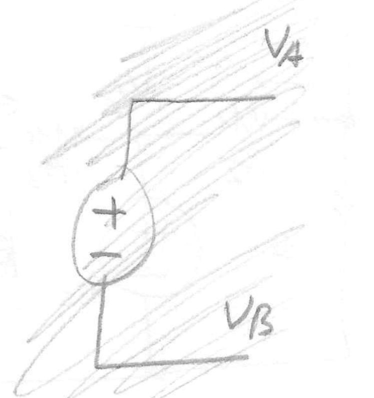


method 1



method 2

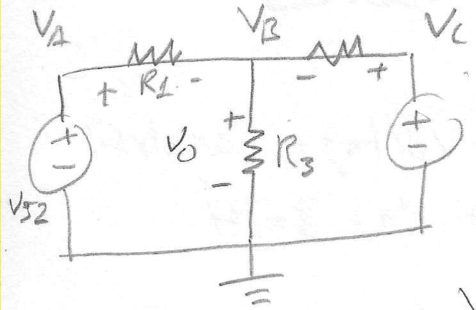
Super Node



method 3

16.2 Use Method 2

KCL at B $\rightarrow$ $i_1 + i_2 - i_3 = 0$



$$\frac{V_A - V_B}{R_1} + \frac{V_C - V_B}{R_2} - \frac{V_0}{R_3} = 0$$

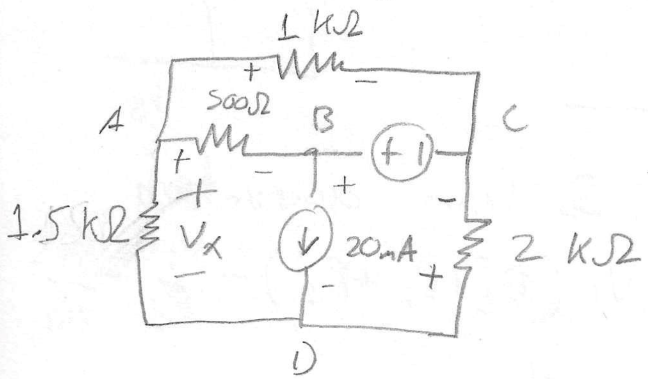
$$-V_B\left(R_1^{-} + R_2^{-} + R_3^{-}\right) + \frac{V_A}{R_1} + \frac{V_C}{R_2} = 0$$

$V_A = V_{S1}$, $V_C = V_{S2}$

So $V_B\left(R_1^{-} + R_2^{-} + R_3^{-}\right) = \frac{V_{S1}}{R_1} + \frac{V_{S2}}{R_2}$ ✓

Ex) choose a Ground wisely

3-15



C should be Ground

KCL at A

$-i - i - i = 0$

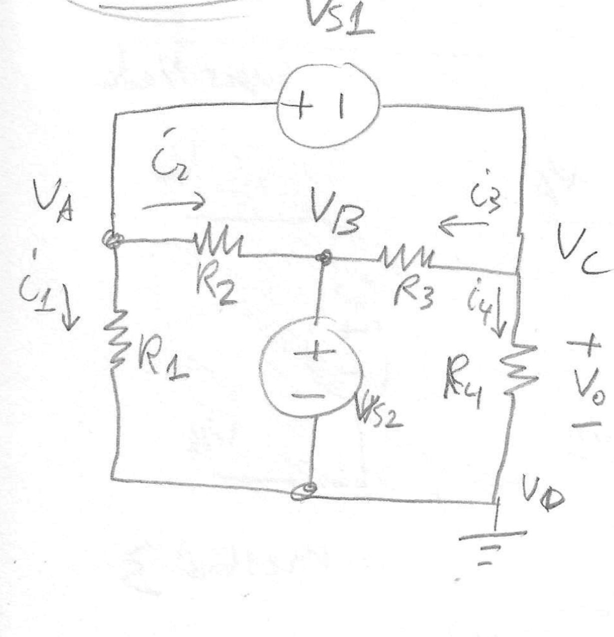
$$-\left(\frac{V_A - V_D}{1.5k\Omega}\right) - \frac{V_A - \cancel{V_B}^{10}}{500} - \frac{V_A - \cancel{V_C}^{0}}{1k\Omega} = 0$$

KCL at D

$$+20mA + \frac{V_A - V_D}{1.5k\Omega} - \frac{V_D}{2k\Omega} = 0$$

into D   into D   out of D

3-17



Node-Voltage Equations

Method 3 is needed, we used 2 already

$V_D = 0 \rightarrow V_B = V_{S2}$ (method 2)

make a supernode boundary

Supernode equation KCL

$i_1 + i_2 + i_3 + i_4 = 0$

$$\frac{V_A}{R_1} + \frac{V_A - V_{S2}}{R_2} + \frac{V_C - V_{S2}}{R_3} + \frac{V_C}{R_4} = 0$$

$$\rightarrow V_A\left(R_1^{-} + R_2^{-}\right) + V_C\left(R_3^{-} + R_4^{-}\right) = V_{S2}\left(R_2^{-} + R_3^{-}\right)$$

Apply fundamental property of node voltages inside supernode $\rightarrow V_A - V_C = V_{S1}$

→ ungrounded voltage source constrains the difference between the two unknown node voltages inside the supernode, so now we need 2 equations and 2 unknowns

so $V_A(R_1^- + R_2^-) + V_c(R_3^- + R_4^-) = V_{S2}(R_2^- + R_3^-)$

and $V_A - V_c = V_{S1} \rightarrow V_A = V_{S1} + V_c$

done

p92

3-2 Mesh-Current Analysis

mesh currents are analysis variables that are useful in circuits containing many elements connected in series

Loop vs mesh

closed path formed by passing through an ordered sequence of nodes w/o passing thru any node more than once

A Loop not enclosing an element

mesh current restricted to planer circuit

(No cross overs)

(window pane circuit)

→ To define a set of variables, associate a mesh current with each window pane and assign a reference direction

All mesh are taken clockwise

Mesh currents are variables not representing actual physics phenomenon

→ Elements around the perimeter are contained in only one mesh, interior elements are in two meshes

→ Element with two meshes, two meshes circulate in opposite direction (the mesh currents)

KCL: net current thru element is the difference of the two mesh currents

∴ If the Kth two-terminal element is contained in meshes X and Y, then the element current can be expressed in terms of the two mesh currents as

$$i_K = i_X - i_Y \qquad 3-9$$

where X is the mesh whose reference direction agrees with the reference direction of i_K

3-9 is a KCL constraint at the element level

if the element is in only 1 mesh, then

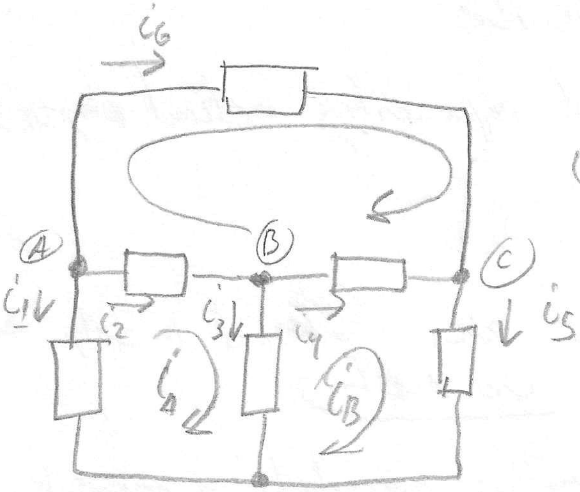
$$i_K = i_X \quad \text{or} \quad i_K = -i_Y$$

depending on wether the reference direction for the element current agrees or disagrees with the reference direction of the mesh current

→ i_K can be expressed in terms of no more than two mesh currents

---

Ex p 93 3-20



$i_A = 10$ A

$i_B = 5A$

$i_C = -3A$

$i_1 = -10$

$i_2 = 13$

$i_3 = 5$

$i_4 = 8$

$i_5 = 5$

$i_6 = -3$

KCL A

$-i_1 - i_2 - i_6 = 0$

KCL B

$i_2 - i_3 - i_4 = 0$

KCL C

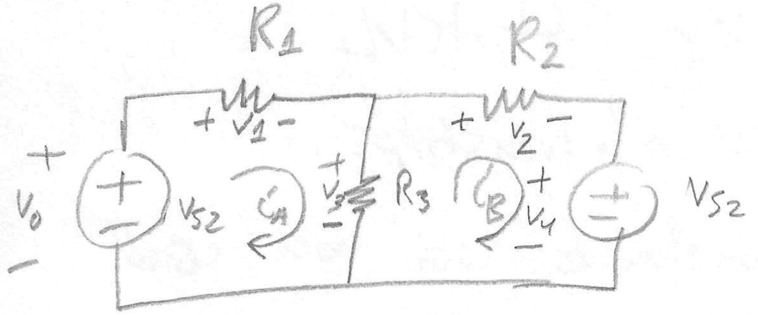
$i_6 + i_4 - i_5 = 0$

Strategy

want to use mesh currents to formulate circuit equations

→ use elements and connection constraints, except KCL constraints are not explicitly written

→ use fundamental property of mesh currents to express the element voltages in terms of the mesh currents



If we express element voltages in terms of mesh currents

we can avoid using the element currents and work only with element voltages and mesh currents

We write KVL constraints around each mesh

Mesh A: $-v_0 + v_1 + v_3 = 0$

mesh B: $v_2 + v_4 - v_3 = 0$

Use fundamental property of mesh currents, write element voltages in terms of the mesh currents and input voltages

$$v_1 = R_1 i_A \qquad v_0 = v_{S1}$$

$$v_2 = R_2 i_B \qquad v_4 = v_{S2}$$

$$v_3 = R_3 (i_A - i_B)$$

So rewrite KVL equations

$$-v_{S1} + R_1 i_A + R_3 (i_A - i_B) = 0$$

$$R_2 i_B + v_{S2} - R_3 (i_A - i_B) = 0$$

$$v_{S1} = i_A (R_1 + R_3) - R_3 i_B$$

$$\rightarrow \quad v_{S2} = i_A R_3 - i_B (R_3 + R_2) \qquad (3\text{-}12)$$

every method must satisfy KCL, KVL

and element $i-v$ relationships

to write the element constraints we have used

KCL $\rightarrow$ $i_1 = i_A$, $i_2 = i_B$, $i_3 = i_A - i_B$

$\rightarrow$ mesh current analysis implicitly satisfies KCL when element constraints are expressed in terms of the mesh currents

$\rightarrow$ fundamental property of mesh currents ensures that KCL constraints are satisfied [we already did fundamental property of node voltages]

(3-4) $v_A(R_1^- + R_2^-) - v_B R_2^- = i_S$

$-R_2^- v_A + v_B(R_2^- + R_3^-) = 0$

Mesh Current Summary

1.) Identify a mesh current with every mesh and a voltage across every circuit element

2.) Write KVL connection constraints in terms of element voltages around every mesh

3.) Use KCL and the $i-v$ relationship of the elements to express the element voltages in terms of the mesh currents

4.) Substitute the element constraints from step 3 into step 2 connection constraints $\rightarrow$ then arrange result equations to standard form recall,

$$\# \text{ of KVL constraints is } \overset{\text{elements}}{\mathcal{E}} - \overset{\text{nodes}}{N} + 1$$

window panes in a planer circuit generate $\mathcal{E}-N+1$ independent mesh currents

→ Mesh analysis is for circuit w/ many elements ($\mathcal{E}$ large) connected in series (also N large)

---

p94 Writing Mesh-Current Equations by Inspection

from equations (3-12), there is a similar coefficient symmetry observed in node equations

$$(3\text{-}12)\quad \begin{aligned} (R_1+R_3)i_A - R_3 i_B &= V_{S1} \\ -R_3 i_A + (R_2+R_3)i_B &= -V_{S2} \end{aligned}$$

$$(R_1^- + R_2^-)V_A - R_2^- V_B = i_S$$

$$-R_2^- V_A + (R_2^- + R_3^-)V_B = 0$$

→ we can see R_3 is in both meshes

→ $\underbrace{(R_1+R_3)}_{\text{Sum of } R\text{'s in mesh } A} i_A$ and $\underbrace{(R_2+R_3)}_{\text{Sum of } R\text{'s in mesh } B} i_B$

This occurs in planer circuits containing R's and independent voltage sources

consider R, it contained in mesh A only

$$\rightarrow V = R(i_A - 0) = R\,i_A$$

or ~~R~~ contained in A and adjacent B

$$V = R(i_A - i_B)$$

(22) following conclusions

Voltage across R_s in mesh A involves

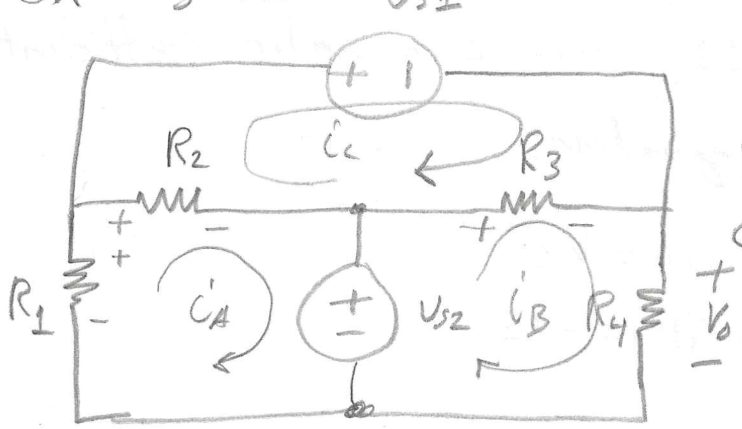
1.) i_A times sum of R_s in mesh A

2.) minus i_B times sum of R_s common to mesh A and mesh B

3.) minus similar terms for any other mesh adjacent to mesh A with a common resistance

KVL must be satisfied

Ex 3-22



from inspection

A: $i_A(R_1+R_2) - i_c(R_2) + V_{s2} = 0$

B: $i_B(R_3+R_4) - i_c(R_3) - V_{s2} = 0$

C: $i_c(R_2+R_3) - i_A(R_2) - i_B(R_3) + V_{s1} = 0$

$$\rightarrow \begin{bmatrix} R_1+R_2 & 0 & -R_2 \\ 0 & R_3+R_4 & -R_3 \\ -R_2 & -R_3 & R_2+R_3 \end{bmatrix} \begin{bmatrix} i_A \\ i_B \\ i_C \end{bmatrix} = \begin{bmatrix} -V_{s2} \\ +V_{s2} \\ -V_{s1} \end{bmatrix}$$

Symmetrical

p97

Mesh Equations With Current Sources

Voltage across current sources is not related to its current.

→ To deal with Voltage Sources (Methods)

1.) If the current source is in parallel with a resistor → equivalent source transform
   → eliminates a mesh and reduces # of equations by 1

2.) if the current source is contained in only 1 mesh, then that mesh current is determined by the source current
   → move known mesh to <u>source side</u> in final step then proceed as normal
   → 1 less equation than # of meshes

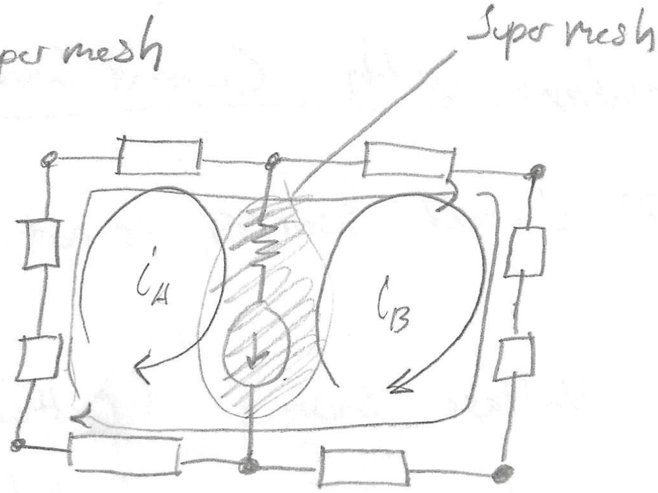
3.) if the current source is not in parallel with a resistor, or in 2 meshes, create a <u>Supermesh</u> by excluding the current source and any elements connected in series with it
   → write a mesh equation around the supermesh using i_A and i_B
   → Proceed as normal
   - We have 1 equation short cuz A and B are included in the supermesh

   → fundamental Property of mesh currents says

$$i_A - i_B = i_S$$

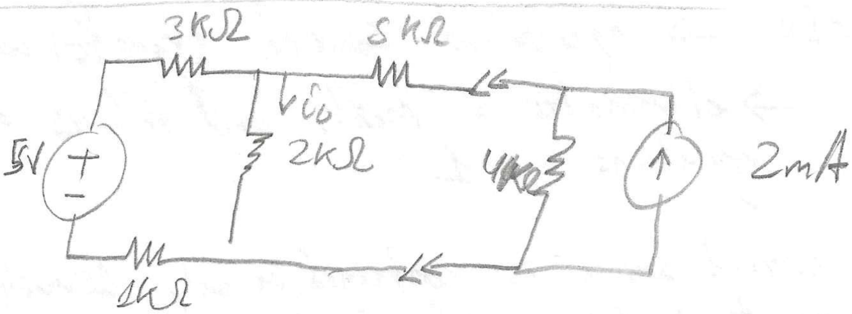
This is one extra relationship needed

3-23 Super mesh

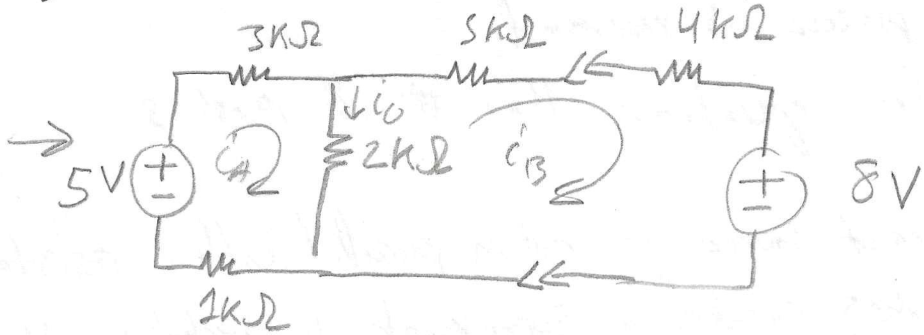


Ex

3-24



Method 1 → source transformations

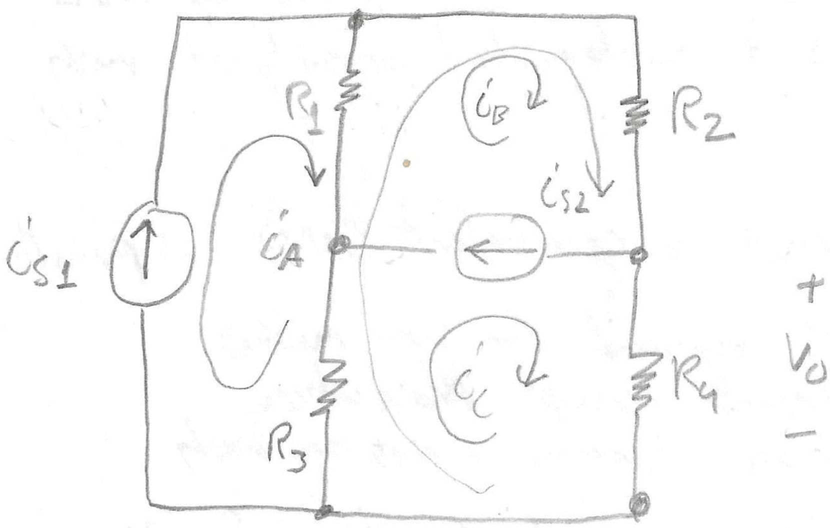


→ A: $i_A(6k) - i_B(2k) = 5V$

$i_B(11k) - i_A(2k) = -8$

$i_o = i_A - i_B$

Ex (3−10) 3−25



method 3: Supermesh

Voltages around supermesh

$i_C(R_3+R_4)+i_B(R_1+R_2)$

$-i_A(R_1+R_3)=0$

for supermesh, when forming KVL use i_C and i_B

method 2 don't forget

$i_A=i_{S1}$ $i_{S2}=i_B-i_C$

→

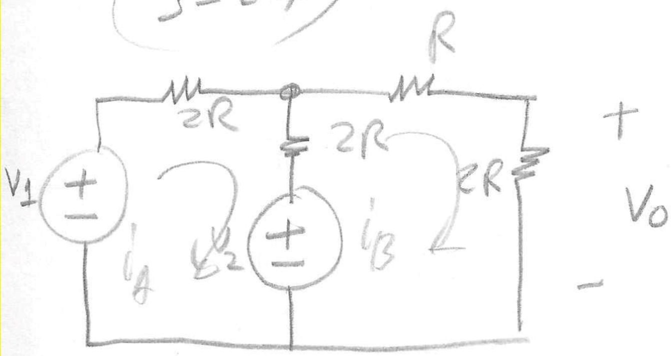
$$i_C(R_3+R_4)+(i_{S2}+i_C)(R_1+R_2)-i_{S1}(R_1+R_3)=0$$

$$i_C(R_3+R_4+R_1+R_2)=i_{S1}(R_1+R_3)-i_{S2}(R_1+R_2)$$

$$V_0=R_4 i_C$$

Ex 3−19

(3−27)



KVL

A: $\cancel{-V_1+i_A(2R)}+(2R)(i_A-i_B)$

by inspection!

$$i_A(2R+2R)-i_B(2R)-V_1+V_2=0$$

$$i_B(R+2R+2R)-i_A(2R)-V_2=0$$

(26) Summary of Mesh-Current Analysis p100

Mesh-current equations can always be formed by KVL + element constraints + fundamental property of mesh currents

1.) Simplify the circuit → equivalent series or parallel

2.) Mesh equations required for super meshes and all other meshes except those where current sources are contained in only one mesh

3.) use KVL to write mesh equations for the meshes identified in (2), Express element voltages in terms of mesh currents or voltage produced by independent voltage sources

4.) Write expressions relating the mesh currents to the currents produced by independent current sources

5.) Substitute expressions from (4) into mesh equations from (3), make equation in standard form

6.) Solve

p100, 3-3 Linearity Properties

A circuit is linear if it can adequately be modeled using only linear elements and independent sources

→ outputs are linear functions of inputs

circuit <u>inputs</u> are signals produced by external sources

→ A function is said to be linear if it has two properties

1.) homogeneity, output is proportional to input

$$f(Kx) = K f(x) \quad (3\text{-}16)$$

2.) Additivity, output of two (or more) inputs added is equivalent to the addition of each signal applied individually

$$f(x+y) = f(x) + f(y) \quad (3\text{-}17)$$

for circuit analysis
homogeneity is called proportionality
additivity is called superposition

(28)

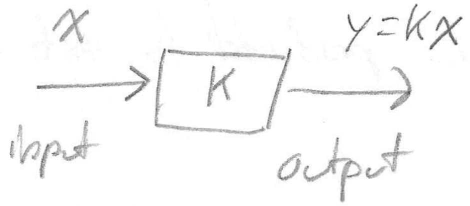
p 101 The proportionality Property

→ applies to circuits w/ 1 input

linear resistive circuits

input – output relationship

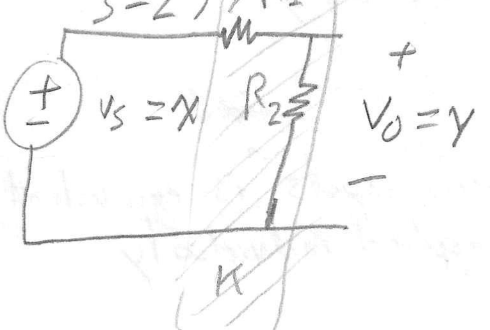
$$y = kx$$



3-28

→ ratio of output and input dominates much of circuit design and analysis, for now we are restricted to $K \leq 1$

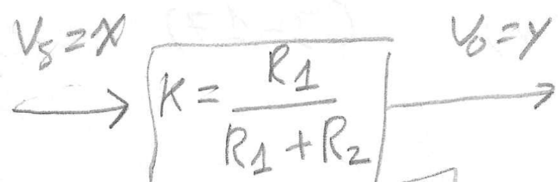
3-29



Proportionality only applies when input/output are current or voltage

→ Not apply to output power as $p = iv$

→ not linearly related to input i or v

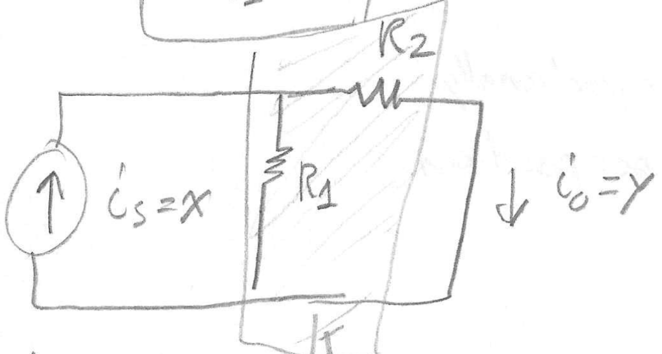


$$K = \frac{R_1}{R_1 + R_2}$$

Voltage division → $V_0 = \left(\frac{R_2}{R_1 + R_2}\right) V_s$

$x = V_s$
$y = V_0$

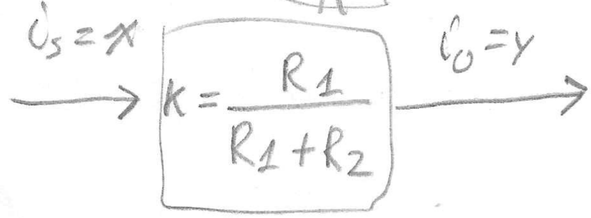
K



Current division

$$i_0 = \left(\frac{R_1}{R_1 + R_2}\right) i_s$$

$x = i_s$, $y = i_0$ $\quad k = \frac{R_1}{R_1 + R_2}$



$$K = \frac{R_1}{R_1 + R_2}$$

Ex Design 3-11 p 102

$K = \frac{V_o}{V_s} = 0.67$

$\rightarrow K = 0.67 = \frac{R_2}{R_1 + R_2}$ $\rightarrow R_2 = kR_1 + R_2 k$

$R_2 - R_2 k = kR_1$

$R_2 = \frac{kR_1}{(1-k)}$

$= 2R_1$

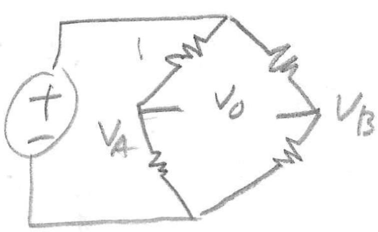
tolerance of 5%

$\rightarrow R_2 = 20k\Omega$

$R_1 = 10k\Omega$

if 20% try $R_2 = 68k\Omega$, $R_1 = 33k\Omega$

Ex 3-12 p 102 7th ed



2 Voltage dividers

$V_A - V_B$, fundamental property of node voltages

Unit output Method

$Y = Kx$ (3-18)

find k by assuming output of one unit and determine input required to produce that unit output.

1.) unit output assumed $V_o = 1\,V$ or $i_o = 1A$

2.) the input required to produce that unit output is found by KCL, KVL, Ohm's Law

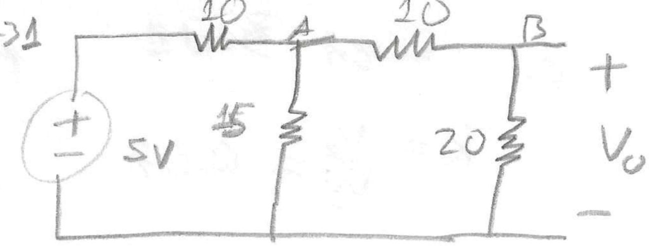
3.)

$K = \frac{\text{output}}{\text{Input}} = \frac{1}{\text{Input for unit output}}$

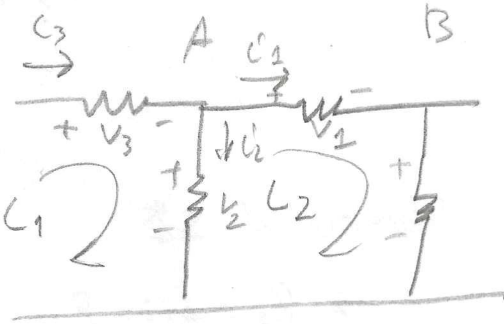
30

3 - 13 p103

Fig 3-31



Use unit output to find V_O, so assume $V_o = 1$



Then $i_o = \frac{1}{20} = 0.05\ A$

KCL at B →

L2 KVL

$\cancel{V_1} + V_o - V_2 = 0$ → $R_2 i_2 = \overset{1/2}{\cancel{V_1}} + \overset{1}{\cancel{V_o}}$

$= 1.5 = V_2$

$i_2 = \frac{1.5}{15} = 0.1\ A$

So $i_3 = i_2 + i_1 = 0.15\ A$

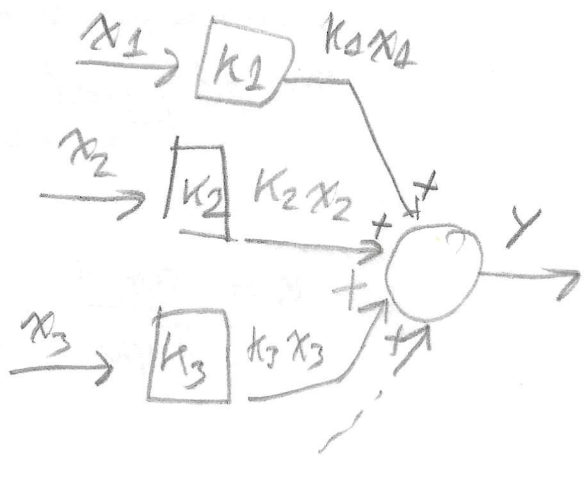
$V_3 = 1.5\ V$ $V_s = V_3 + V_2 = 3\ V \rightarrow K = \frac{1}{3}$

---

p105 Additivity Property

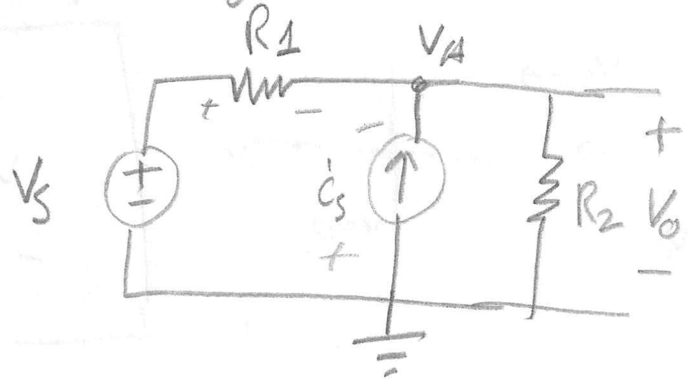
any output current or voltage of a linear resistive circuit with multiple inputs can be expressed as a linear combination of the several inputs

(3-19) $Y = K_1 X_1 + K_2 X_2 + K_3 X_3 \ldots$

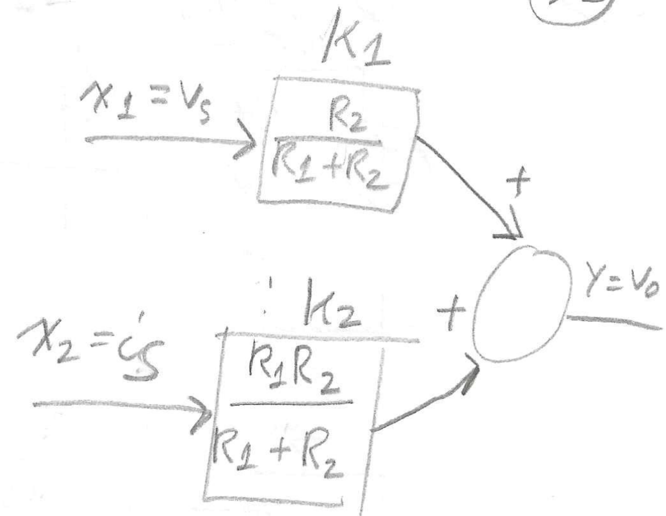


3-33

Figure 3-34



Superposition



Block Diagram

Use Node Analysis → KCL A

$$i_s + \frac{V_s - V_A}{R_1} - \frac{V_A}{R_2} = 0 \rightarrow \quad i_s + \frac{V_s}{R_1} = V_A\left(R_1^{-1} + R_2^{-1}\right)$$

$$V_0 = V_A \rightarrow \quad V_0 = \left(\frac{R_2}{R_1+R_2}\right)V_s + \left(\frac{R_1R_2}{R_1+R_2}\right)i_s \qquad (3\text{-}20)$$

Supperposition Principle

from $y = k_1x_1 + k_2x_2 + k_3x_3 \dots$

each input source is independent of all other input

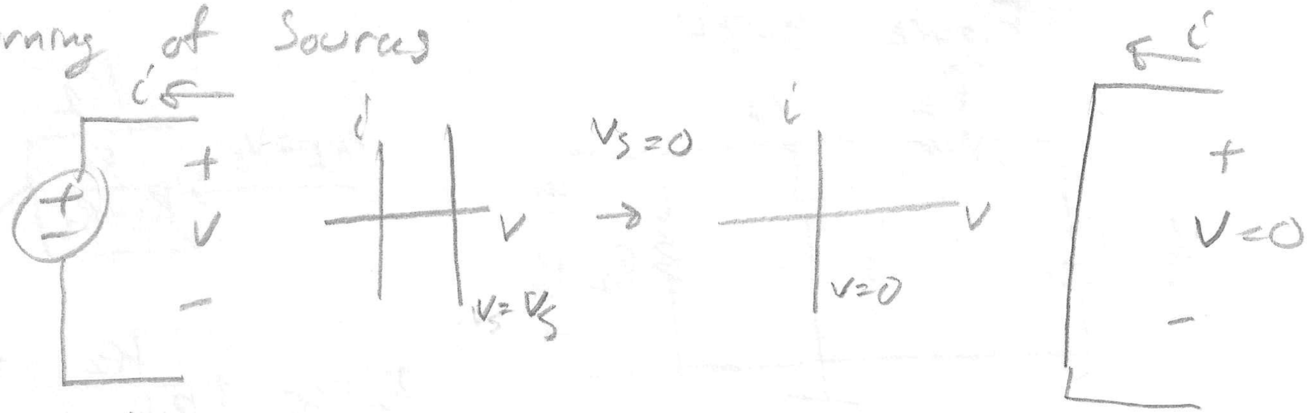
→ So the output can be found by finding the contribution from each source acting alone, then adding the individual responses to obtain the total response

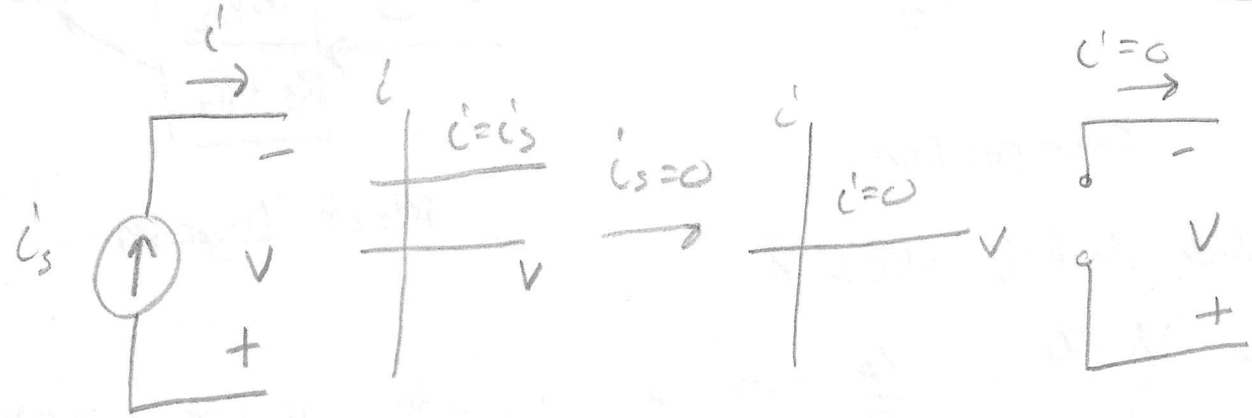
1.) 'Turn off' all but one Independent sources, find output of that source ~~alone~~

2.) Repeat for all sources til we have the output due to each source

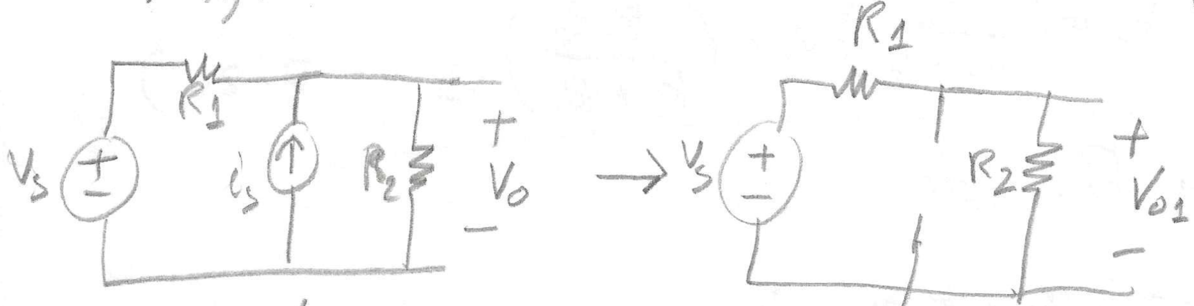
3.) Total output is all independent sources 'on' is algebraic sum of individual outputs

(32) Turning of Sources





Ex fig 3-36

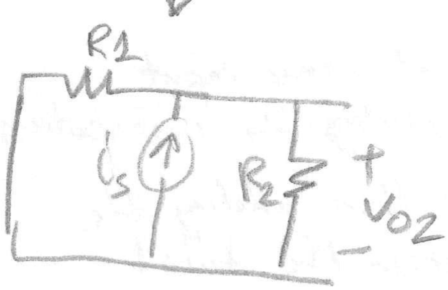


$V_s = V_1 + V_{o1}$

$V_{o1} = V_s - V_1$

$= R_2 i$

$= \dfrac{R_2}{R_1+R_2} V_s$



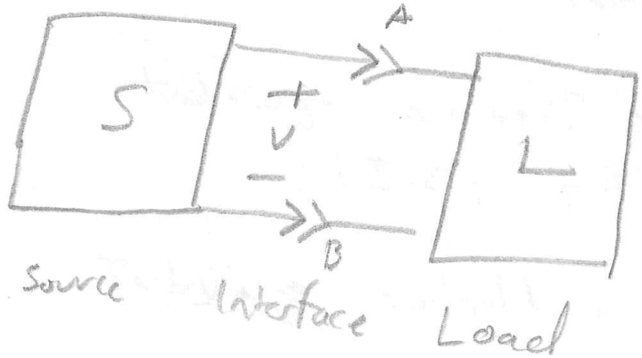
$$V_{o2} = i_{o2} R_2$$
$$= \frac{R_1}{R_1+R_2} i_s (R_2)$$
$$= \frac{R_1 R_2}{R_1+R_2} i_s$$

Superposition!

$$V_o = V_{o1} + V_{o2} = \frac{R_2}{R_1+R_2} V_s + \frac{R_1 R_2}{R_1+R_2} i_s$$

Ex 3-14 p 107 — Another voltage divider

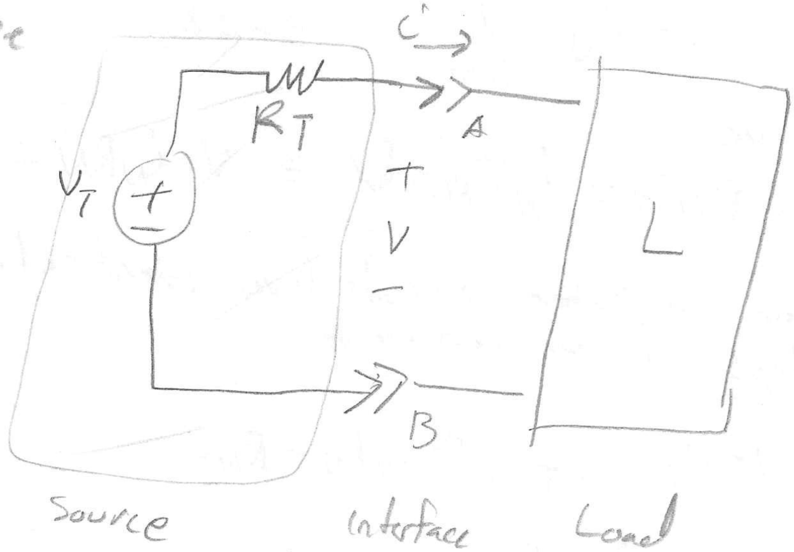
p109 Thévenin and Norton Equivalent circuits



Interface is a connection between circuits, they are frequent so we have special tools + analysis ~~methods~~

Signals from the source circuit delivered to the Load circuit

fig 3-41, two terminal interface



Thévenin and Norton equivalent circuits shown in (3-42) are valuable tools for dealing with circuit interfaces.

Condition for equivalent circuits exist:

If the source circuit in a 2 terminal Interface is linear, then the interface signals V and i do not change when the source circuit is replaced by its Thévenin or Norton equivalent

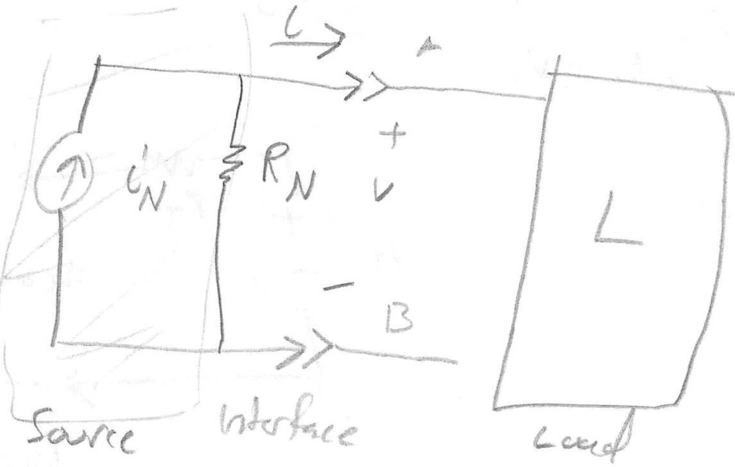


Fig 3-42

→ Load doesn't need to be Linear

→ Loads can be linear storage elements called capacitors + inductors

(34) Thévenin and Norton are practical sources

i-v characteristics are same

You can interchange them

→ KVL + Ohm's Law to Thevenin equivalent

A-B → $V = V_T - iR_T$ (3-21)

Next KCL, Ohm's Law to Norton equivalent
at A-B $i_N - \frac{V}{R_N} - i = 0$

$$i = i_N - \frac{V}{R_N} \qquad (3\text{-}22)$$

So we have
$$R_N i = i_N R_N - V \rightarrow V = i_N R_N - R_N i \qquad (3\text{-}23)$$

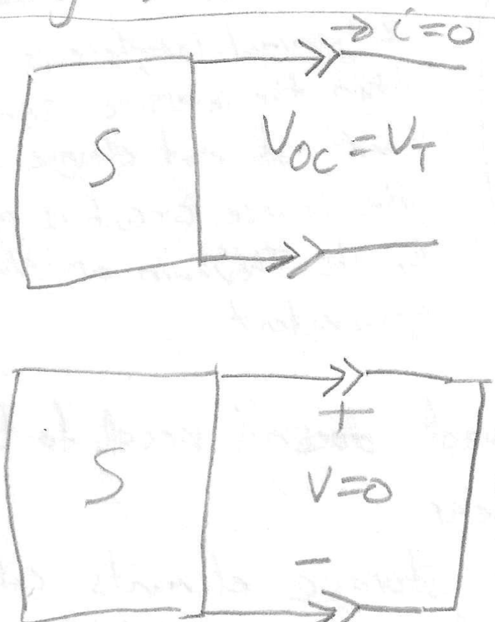
The Thevenin and Norton circuits have identical i-v relationships so we can write

$$V = V_T - iR_T \,, \quad V = i_N R_N - R_N i$$

$$\Longleftrightarrow \begin{array}{l} R_N = R_T \\ i_N R_N = V_T \end{array} \qquad (3\text{-}24)$$

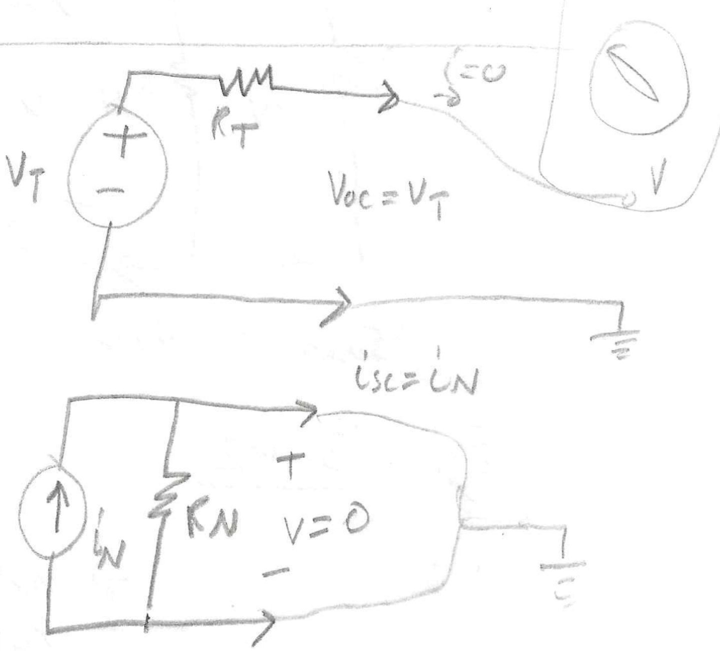
Digital multimeter

Fig 3-43



and $i_{SC} = i_N$

all i diverted to short circuit



So

$$V_T = V_{oc}$$
$$i_N = i_{sc}$$
$$R_N = R_T = V_{oc}/i_{sc}$$

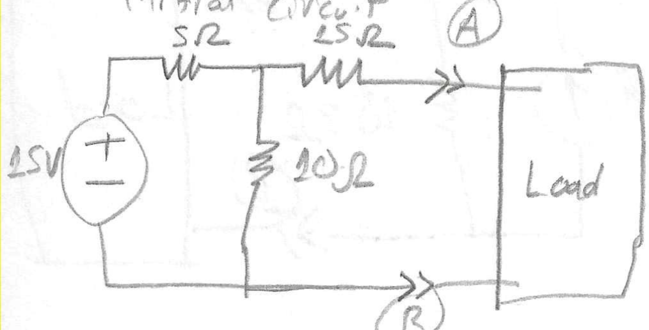
---

p 112 Applications of Thévenin and Norton Equivalent circuits

→ replacing a complex circuit by its Thévenin or Norton equivalent can greatly simplify the analysis and design of interface circuits

Fig 3-44

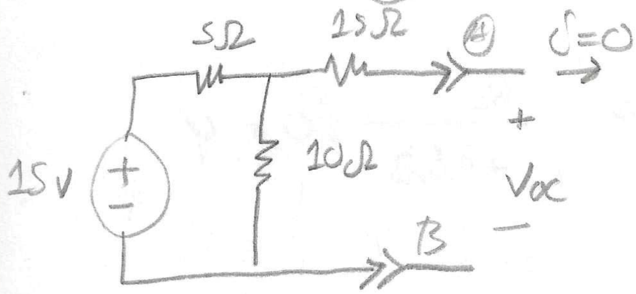
initial circuit



→ select Load so the source circuit delivers 4V

We need the Thevenin or Norton equivalent

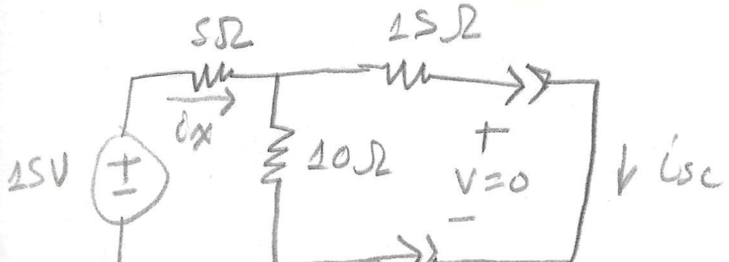
→ So we need V_{oc}, i_{sc}



as $i=0$ we get

$$V_T = V_{oc} = \frac{10}{10+5} \times 15 = 10V$$

→ we have Voltage Open circuit



to find i_{sc} (current short circuit)

$$i_x = \frac{15V}{R_{eq}} \qquad R_{eq} = 5 + 15 \parallel 10\ \Omega = 11\ \Omega$$

$$\rightarrow i_x = i_1 + i_{sc} \rightarrow i_{sc} = \frac{V_1}{15} = \frac{i_x}{15(10^{-1}+15^{-1})}$$

$$i_x = V_1(10^{-1}+15^{-1})$$

$$V_1 = \frac{i_x}{(10^{-1}+15^{-1})}$$

current division

$$i_{sc} = \frac{10}{10+15} i_x$$

(36) So $i_{sc} = i_N$ So $i_{sc} = i_N = 0.545\ A$

And $V_T = 10\ V$

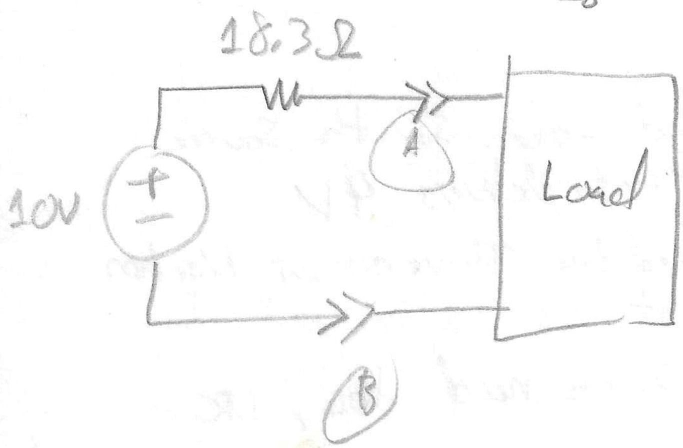
So $R_T = R_N = \frac{V_{oc}}{i_{sc}} = \frac{V_T}{i_N} = \frac{10}{0.545} = 18.3\,\Omega$

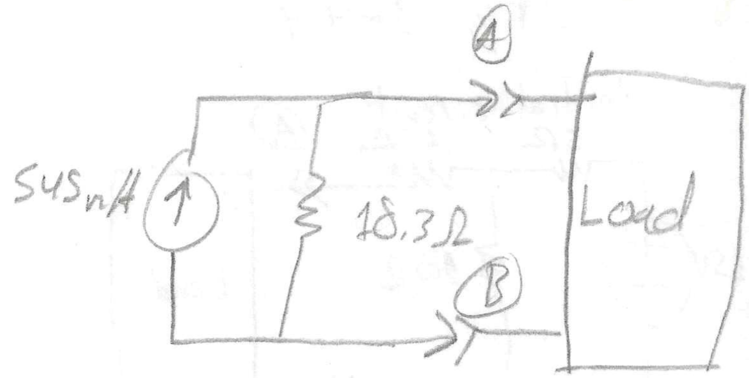
recall (3-25) $V_T = V_{oc}$

$i_N = i_{sc}$

$R_N = R_T = \frac{V_{oc}}{i_{sc}}$

So





So use V_T, $\frac{R_L}{R_L + R_T} V_T \rightarrow \frac{R_L}{R_L + 18.3} 10 = 4$

$R_L = 12.2\,\Omega$