Chapter 1

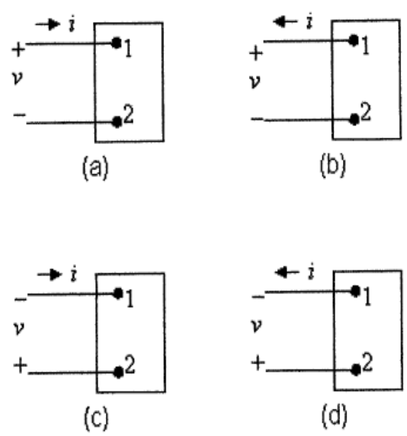
Passive sign convention:

1. Whenever the reference direction for the current in an element is in the direction of the reference voltage drop across the element, use the positive sign in any expression that relates the voltage to the current. V=RI

   - P=IV. After numerical substitution, if the numerical sign of P is negative => element is producing energy. After numerical substitution, if the numerical sign of P is positive => element is consuming energy

2. Whenever the reference direction for the current in an element is in the direction of the reference voltage rise across the element, use the negative sign in any expression that relates the voltage to the current. V= -RI

   - P=-IV. After numerical substitution, if the numerical sign of P is negative => element is producing energy. After numerical substitution, if the numerical sign of P is positive => element is consuming energy



Chapter 2

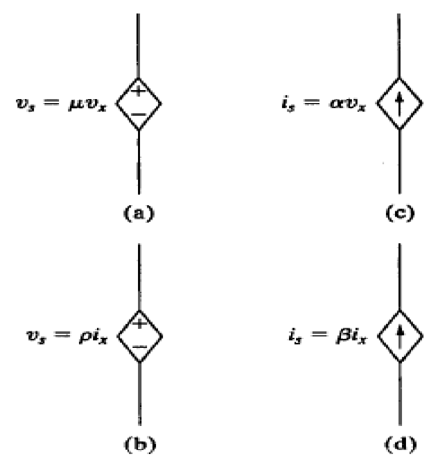
Independent and Dependant sources

a. Voltage-controlled voltage source. Unit is V. Current across it is unknown

b. Current-controlled Voltage source. Unit is V. Current across it is unknown

c. Voltage-controlled current source. Unit is I. Voltage across it is unknown

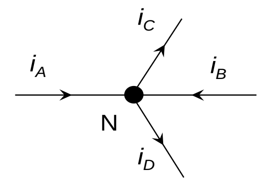
d. Current-controlled current source. Unit is I. Voltage across it is unknown



Circuit Terminologies:

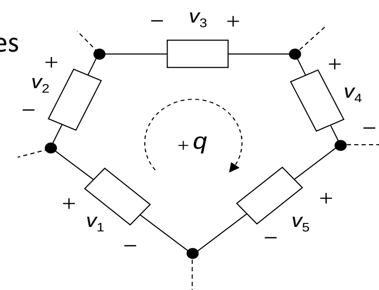
- An **essential node** is the junction of three or more circuit elements.
- An **essential branch** is a branch that connects two essential nodes without passing through an essential node.
- A **mesh** is a loop that does not enclose any other loop.

KCL:



KCL may be stated as follows: *at any instant of time, the sum of currents entering a node is equal to the sum of currents leaving the node*. At node N, for example, KCL gives: $i_A + i_B = i_C + i_D$. Alternatively, $i_A + i_B - i_C - i_D = 0$, where currents flowing towards a node have been arbitrarily assigned a positive sign, which means that currents flowing away from a node should be assigned a negative sign.

KVL:



KVL may be stated as follows: At any instant of time, the sum of the voltage rises around any loop is equal to the sum of the voltage drops around the loop. An equivalent statement of KVL is: A*t any instant of time, the algebraic sum of the voltages around any loop is zero*, since voltage drops and voltage rises are assigned opposite signs

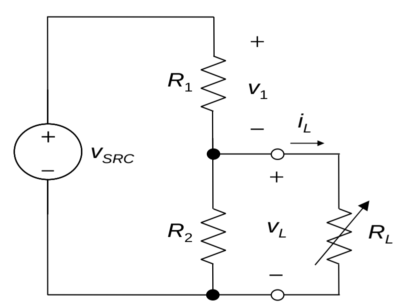
Chapter 3

- In a series connection of resistors, the same current flows through all the resistors, and voltages across the individual resistors may be added algebraically to obtain the total voltage across the series combination
- In a parallel connection of resistors, the same voltage exists across all the resistors, and the currents through the individual resistors may be added algebraically to obtain the total current

Voltage divider

- If a load R_L is connected across R_2, then

$$\frac{v_L}{v_{SRC}} = \frac{(R_2 \parallel R_L)}{R_1 + (R_2 \parallel R_L)}$$



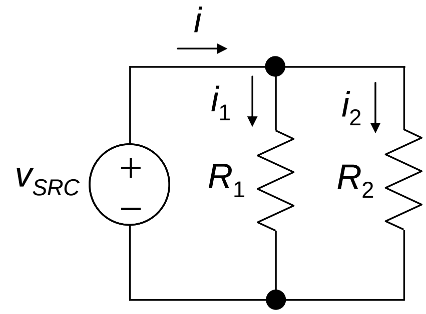
Current divider

A resistive current divider consists of two or more resistors in parallel.

$$i_1 = \frac{R_2}{R_1} i_2 \qquad i_2 = \frac{R_1}{R_2} i_1$$

or

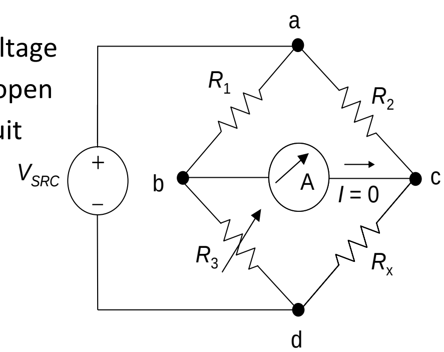
$$i_1 = \frac{R_2 i}{R_1 + R_2} \qquad i_2 = \frac{R_1 i}{R_1 + R_2}$$



Wheatstone bridge

When the bridge is balanced, nodes b and c are at the same voltage and no current flows between them. The branch bc could be open circuited, or short circuited, without disturbing the rest of the circuit

$$R_1 R_x = R_2 R_3$$

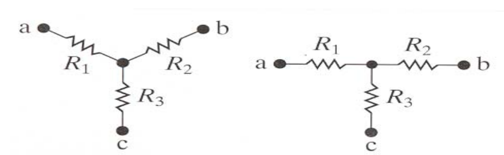


The Δ-Y Transformation is also known as π-T transformation

$$R_1 = \frac{R_b R_c}{R_a + R_b + R_c},$$

$$R_2 = \frac{R_c R_a}{R_a + R_b + R_c},$$

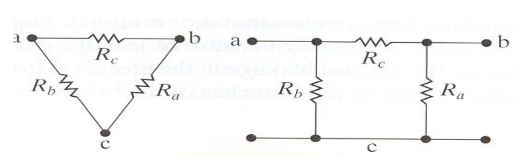
$$R_3 = \frac{R_a R_b}{R_a + R_b + R_c}.$$



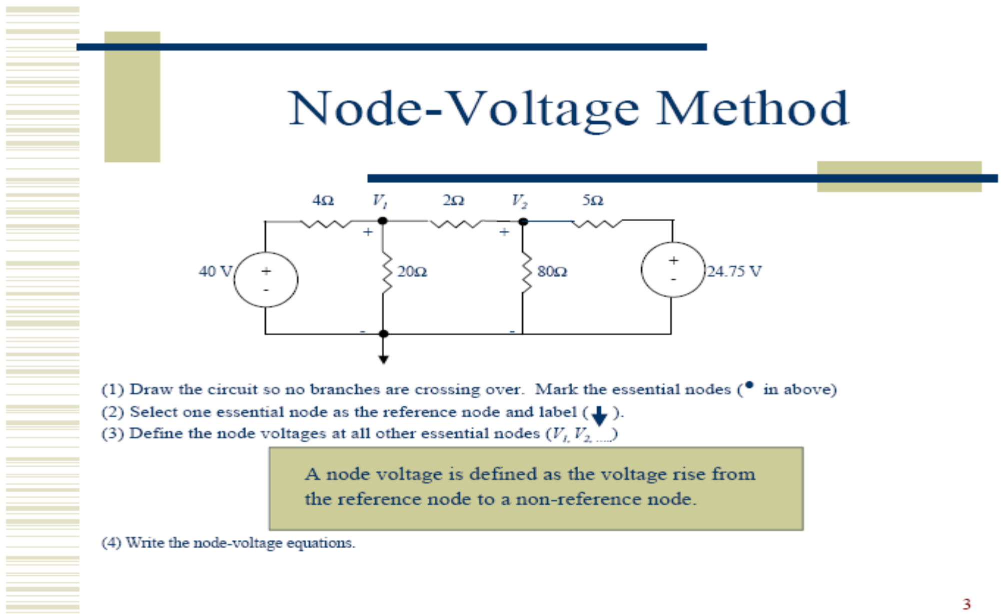
$$R_a = \frac{R_1 R_2 + R_2 R_3 + R_3 R_1}{R_1},$$

$$R_b = \frac{R_1 R_2 + R_2 R_3 + R_3 R_1}{R_2},$$

$$R_c = \frac{R_1 R_2 + R_2 R_3 + R_3 R_1}{R_3}.$$



Chapter 4

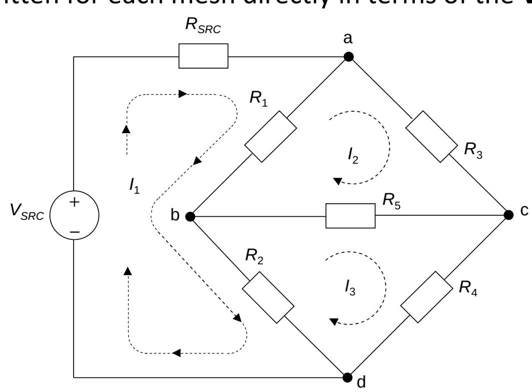


Number of equations to solve for independent sources only = number of essential nodes-1

Number of equations to solve for independent sources + dependant sources = number of essential nodes-1+ equation relating the dependant variables of the source to the other circuit variables

Mesh-Current Method

Equations based on KVL are then written for each mesh directly in terms of the **V**-**I** relations

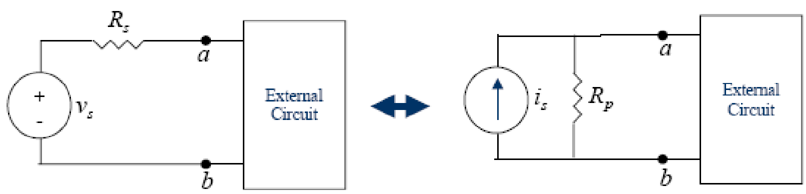


Number of equations to solve for independent sources only = number of meshes

Number of equations to solve for independent sources + dependant sources = number of meshes + equation relating the dependant variables of the source to the other circuit variables

Source Transformation

Given a voltage (current) source, we can construct a current (voltage) source that is equivalent in terms of the external circuit connection.



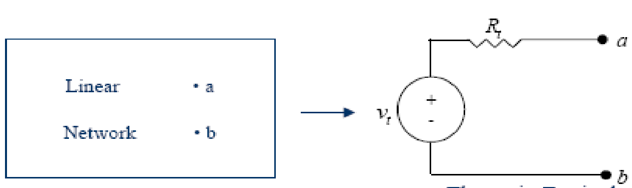
Consider two cases : (i) R_{ab} is short circuit ($R_{ab} = 0$)

(ii) R_{ab} is an open circuit ($R_{ab} = \infty$)

Thevenin and Norton Equivalence

A Thebenin equivalent circuit can be used to represent any circuit made up for linear elements. The advantage of using an equivalent circuit is that an entire set of interconnected circuit elements (sources, resistors, capacitors, inductors, and other linear elements) can be replaced by one independent voltage source in series with a single passive device. This allows us to easily analyze the effects on elements placed at a particular set of terminals.

For example:



Thevenin Equivalent

To find Thevenin equivalent circuit: we need to solve for V_{Th} and R_{Th}

	Independent sources only	Independent and dependant sources
V_{Th}	V_{Th} = V open circuit between a and b, using any circuit technique	V_{Th} = V open circuit between a and b, using any circuit technique

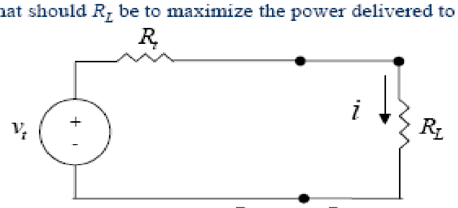
R_{Th}	R_{Th}= R equivalent between a and b, after I desactivate all sources. A voltage source is replaced by a short circuit and a current source replaced by an open circuit.	Inject a test source between a and b. R_{Th} = V_{TEST}/ I_{TEST}. Note that I don't solve numerically for the values of V_{TEST} or I_{TEST}. Instead I aim to find the ratio. A voltage source is replaced by a short circuit and a current source replaced by an open circuit.
R_{Th}	I place a short circuit between a and b. Using any circuit technique find the value of I_{sc}. R_{Th}= V_{Th}/ I_{sc}	I place a short circuit between a and b. Using any circuit technique find the value of I_{sc}. R_{Th}= V_{Th}/ I_{sc}

N.B: If only dependant sources. => Equivalent circuit only R_{Th} =>Inject test source V_{TEST} => R_{Th}=V_{TEST}/I_{TEST}

A Norton equivalent circuit is similar to the Thevenin equivalent circuit except it consists of an independet current source in parallel with a Norton equivalent resistance. It can be obtained by a source transformation on the Thevenin circuit.

Maximum Power Transfer

What should R_L be to maximize the power delivered to R_L?



$$p = i^2 R_L \quad \text{where} \quad i = \frac{v_t}{R_t + R_L}.$$

$$p = \frac{v_t^2}{(R_t + R_L)^2} R_L$$

$$\frac{dp}{dR_L} = \frac{v_t^2}{(R_t + R_L)^2}\left[1 - \frac{2R_L}{R_t + R_L}\right] \Rightarrow 0 \quad \longrightarrow \quad 1 - \frac{2R_L}{R_t + R_L} = 0$$

$$R_t + R_L = 2R_L$$

$$R_t = R_L$$

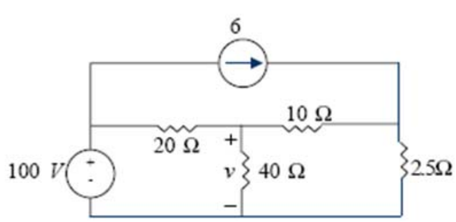
Maximum power transferred to the load occurs when the load resistance is equal to the Thevenin resistance

In case the circuit is more complicated, you need to first find the thevenin equivalent first.

Superposition

If a linear system is excited by more than one independent source, we can determine the total response of the system by determining the response to each independent source separately and then summing the individual responses.

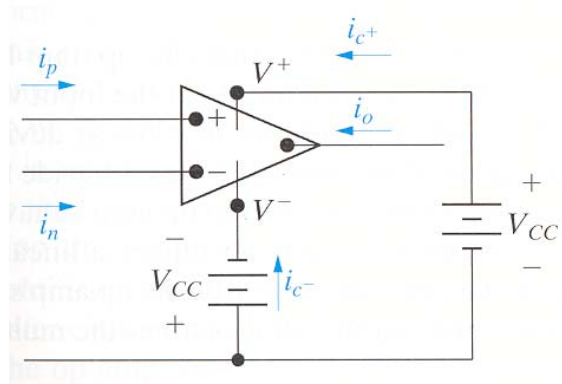
Example



Chapter 5

1) $i_n = i_p = 0$ always

2) $V_p = V_n$ always (numerical value depends on circuit)



3 regions of operations for OP-Amp.

If after solving we find $|V_{out}| > |V_{cc}|$

=> Op-Amp saturated

=> effectively $|V_{out}| = |V_{cc}|$