Important Equations and concepts

Last update (6/12/06)

Chapter 1

q= Charge C
E= Electric Field V/m force per unit charge
V= Voltage Work per unit charge J/C=Volts
I= Current Charge per second C/s=Amperes
P=Power = Watts which is Volts Amperes or Joules per seconds

$v = \frac{dw}{dq}$ where v is in Volts w is in Joules and q is in Coulomb

$i = \frac{dq}{dt}$ where i is in Amperes, q is in Coulombs and t is in seconds

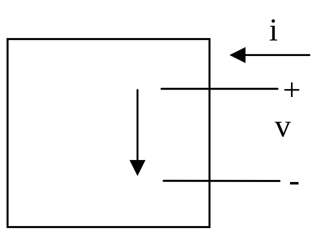
$v = iR = \frac{i}{G}$ where v is in Volts, R is in ohms (Ω), and G is called conductance in 1/Ohms or Siemens (S)

$p = \frac{dw}{dt} = vi = \frac{v^2}{R} = i^2 R =$ where p is in Watts, w is in Joules, and t is in seconds

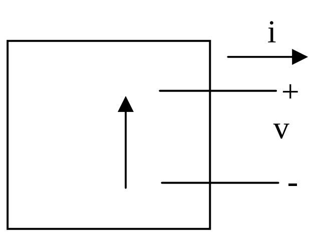
<u>Active element:</u>
A device capable of generating electricity

<u>Passive element:</u>
A device that cannot generate electricity

<u>Passive sing convention:</u> when ever the reference direction of the current **in an element** is in the direction of the reference voltage drop across the element use + sign in any expression that related voltage and current. Otherwise use – sign.



P= + vi



P= - vi

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With passive sign convention, active devices will have – power and passive devices will have + power.

<u>Node:</u> a point where two or more circuit elements meet

<u>Closed-loop or Path:</u> Starting from an arbitrarily selected node, trace a closed path in a circuit through selected circuit elements and return to the original node without passing through any intermediate node more than once.

<u>Kirchhoff's Current Law (KCL):</u> The algebraic sum of all the currents at any node in a circuit equals zero. This is really a statement of conservation of charge

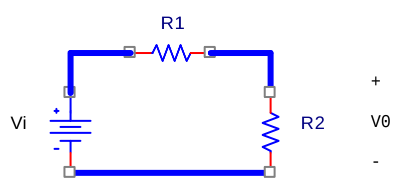
<u>Kirchhoff's Voltage Law (KVL):</u> The algebraic sum of the of all the voltages around any closed path in a circuit equals zero. This is a statement of conservation of energy (work).

Chapter 2

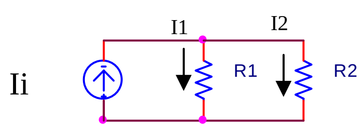
<u>Series resistors</u> $R_{eq} = \sum_i R_i$

<u>Parallel resistors</u> $R_{eq} = \left(\sum_i \frac{1}{R_i} \right)^{-1}$

<u>Voltage divider:</u> $V_0 = V_i \frac{R_2}{R_1 + R_2}$



<u>Current divider:</u> $I_1 = I_i \frac{R_2}{R_1 + R_2}$ and $I_2 = I_i \frac{R_1}{R_1 + R_2}$



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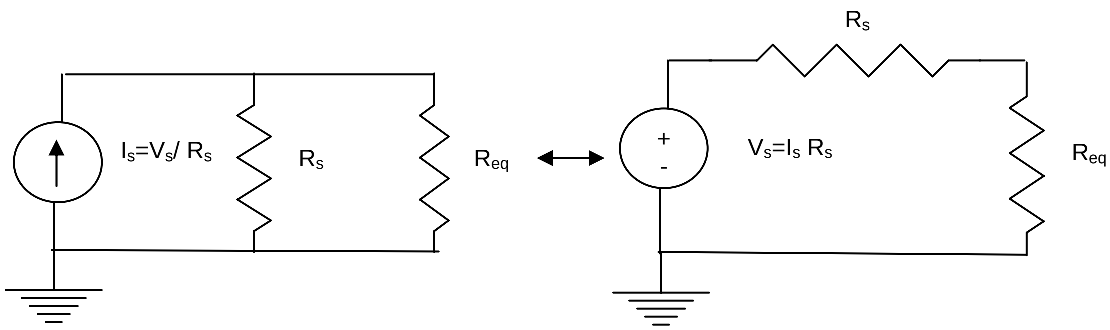
Source Transformation This is a way to go between an independent Voltage and current source to deliver the same power (Current, and Voltage) to the load.



Superposition: this is a process that determines the value of the unknown by focusing on each independent source by itself and deactivating the rest of the independent sources (bringing the values to zero, so voltage sources will be shorted, and current sources will be open) and do this for all independent sources. So, if there are 4 independent sources, we will have 4 contributions due to each of them (while the rest are deactivated) and added together.

Chapter 3

Introduction to Circuit analysis

There are two major methods in this chapter and major definitions.

As electrical and computer engineers and students of circuit we need to know the definitions well

A circuit Element	An entity for which we have terminal characteristics (or have a model for that) such as Ohm's law for resistors
Node	Where 2 or more circuit elements join
Essential Node	A node that three or more circuit elements join
Path	A trace of adjoining circuit elements with no elements included more than once
Branch	A path connecting two nodes
Essential branch	A path that connects two essential nodes without passing through an essential node
Loop	A path whose last node is the same as the starting node
Mesh	Is a loop that does not enclose any other loop
Planar circuit	Is a circuit that can be drawn on a plane with no crossing branches

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Node-voltage method: (works for planar and nonplanar circuits)

- Identified the essential nodes (n+1)
- Select a reference point (one of the essential nodes)
- Each of the other nodes will have a voltage value with respect to the reference node (there will be n unknowns)
- Write down KCL for each node (the non reference ones)
- You will have n equations
- If you have dependent sources in the problem they will introduce other equations and increase the total number of equations and unknowns

Supernode

- When doing Node voltage two of the nodes may have a voltage source in between them
- One can write the equations assuming a current in the source
- This will increase number of unknowns by the value of the current
- However, one can write another equation between the nodes with the voltage source
- It turns out that there is an easier way
  - Assume the super node is a single node and write equations that would do the KCL for the two nodes
  - This equation will have the two node voltages in there
  - Then the equation of the super node that will related the values of the two Voltages via the value of the current source will be added to get the right number of equations and unknowns

Mesh-Current Method (Works on planar circuits only)

- Identify meshes
- Assign current to each mesh
- For each mesh write KVL around the mesh (when working with an edge element in which the element shares the current from two mesh you need to add the two currents according to the appropriate direction
- For n meshes you will have n equations, other equations should be created if we have dependable sources
- If in a mesh you have a current source that defines either the mesh current or the net current resulting from two meshes

Thevenin/Norton equivalents

- These are ways to simplify a given circuit
- The simplification will replace the circuit into a source and a load (resistor at this level)
- The idea is how can we replace a whole circuit (with respect to two ports) so that for a give load the circuit and the replace Thevenin or Norton equivalents will give the same terminal characteristics (power, current, voltage…)

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- **Thevenin Equivalent (V_{th}, R_{th})**
  - Thevenin voltage can be found by the calculating open circuit voltage
    - If here are not independent sources, the open circuit voltage will be zero which mean there is no Thevenin Equivalent voltage source nor a Norton one
  - To find the Thevenin equivalent load (resistance for this chapter)

    Method 1:
    Short circuit the terminals and find the short circuit current $R_{th}=V_{OC}/I_{SC}$ (for this method all the independent sources are active)

    Method 2:
    Use a test voltage at the terminals and fine the current that is pulled from the source then $R_{th}=V_{test}/I_{test}$ (for this method you need to deactivate all of the independent sources and only have the test voltage activated)

    Method 3:
    Sometimes if there are no dependent sources one can just use resistor equivalent to find the R_{th}
- **Norton Equivalent (I_N, R_{th})**
  - The relationship between Thevenin and Norton is source transformation.
  - They share the same R_{th} and Norton is with a current source where Thevenin is with a voltage source
  - In the case of having the short circuit current, for finding the Thevenin equivalent, it should be noted that the short circuit current is the same as the Norton current
- **Condition of Maximum power transfer to the load**:
  - Looking at the inputs of the load find the Thevenin equivalent of the circuit that is driving the load
  - A load with the same value of the Thevenin resistance will be needed for maximum power transfer
  - In that case the power delivered to the load will be $P=\dfrac{V_{th}^2}{2R_{th}}=\dfrac{I_N^2\ R_{th}}{2}$

Chapter 4

- This is the first exposure to the Operational Amplifier elements.
- As every circuit entity, in this class we need to identify the terminal characteristics of the device and then use KCL and KVL and applications such as the Node Voltage, Mesh Currents, and Thev and Nort. Equivalents to the systems
- Ideal Op-Amp
  - Has infinite gain
  - The inverting (V_- or V_n) and non-inverting (V_+ and V_p)

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- We do not allow any current to go into the terminals of inverting and noninverting inputs
- The real ideal Op-Amp does not saturate

For practical purposed we deal with the following

- The out put has the following

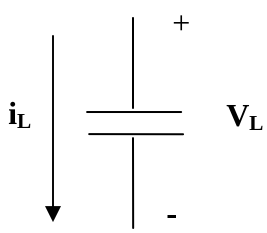
$$V_0 = \begin{cases} -V_{cc} & A(V_p - V_n) < -V_{cc} \\ A(V_p - V_n) & -V_{cc} \le A(V_p - V_n) \le +V_{cc} \\ +V_{cc} & +V_{cc} < A(V_p - V_n) \end{cases}$$

- It should be noted that here we assume the power supplies of V_{cc} and - V_{cc} are powering the Op-Amp and in addition we assume that the open look gain (this is a characteristic of an Op-Amp by design) is A
  - Two important items to remember
    - The inverting input V_- or V_n is called inverting since if that is the only input the output will be – AV_n it is negative of the input
    - The non-inverting input V_+ or V_p are non inverting since if that is the only input the output will be AV_p this is the same sign as the input
- There are two important configuration that all need to know
  - The inverting configuration
  - The non-inverting configuration

Chapter 5

$$i_C = C\frac{dV_C}{dt}$$

$$V_C = \frac{1}{C}\int_0^t i_C\,dt + V_C(t = 0^-)$$



$$V_L = L\frac{di_L}{dt}$$

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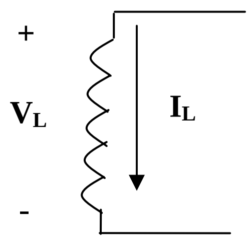

- Once we follow passive sign convention, and calculate the power vi accordingly, if the power is – it is delivering power (the cap or ind were energized and then released energy during the process) and if the power is + the element is absorbing power.
- In general dealing with inductors and capacitor circuits you have to deal with two types of information what are the values for 0 (when switching occurs) which means the voltage or current at t=0+ after the switch the other information is at infinity when the time is few orders of magnitude larger than the time constant we need to see what the voltages and currents are for inductors and capacitor
- Also remember for capacitors v(t-)=v(t+) capacitors do not allow instantaneous changes in the voltage (but the current thru the capacitor can change instantaneously) for inductors they will now allow the instantaneous change in the current in the inductor i(t-)=i(t+)
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