電子與電路學

-電路(Electric Circuit)+電子元件+電子線路(Electronic Circuit)

<DEF> Electric Circuit

A GRAPH - a collection of Vertices(端點) and Edges(連接)
whereby every edge contains excatly one electric component
and, every vertex has a specific electric potent where one of them is defined as 0 volt, i.e. Ground

-measurement
- -Vertex → Electric Potential(V)(電壓): Potential Energy(位能)
- -Edges → Current(I)(電流)
- -Electric Power(P)(電力): $P = IV$
  - -能量以光速前進而非電子

<DEF> Ohm's Law

-$R = \frac{V}{I} = \rho\frac{L}{A}$
- -R (resistor), ρ(resistivity)(電阻率), L(電阻長度), A(電阻截面積)

-$E = \frac{V}{L} = \rho\frac{I}{A} = \rho J$
- -E(electric feild strength), J(current density)

-宏觀(macroscopic)(電磁波長λ>>系統大小): R=V/I
-微觀(microscopic)(電磁波長λ<<系統大小): E=ρJ

<Syntax>

v(t) / i(t): small → time varing value
V / I: capital → average of v(t)/i(t)
v_A / i_A : capital → reference with 0V/0A
v_a / i_a: small → reference with V_A/I_A → (v_a(t)-V_A)/(i_a(t)-I_A)

<DEF> Root Mean Square

$$\widetilde{V_A} = V_A^{(rms)} = \sqrt{\frac{1}{T}\int_{t_0}^{t_0+T} {V_A}^2(t)dt}$$

$$\mathrm{P}_T(t) = \frac{1}{T}\int_{t_0}^{t_0+T} i(\tau)v(\tau)d\tau = \frac{1}{T}\int_{t_0}^{t_0+T} \frac{v(\tau)}{R}v(\tau)d\tau = \frac{1}{T}\int_{t_0}^{t_0+T} \frac{v^2(\tau)}{R}d\tau$$

$$\mathrm{P}_T(t) \propto \frac{1}{T}\int v^2(\tau)d\tau \propto v^{(rms)^2}$$

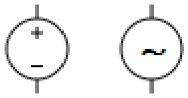
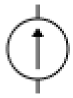
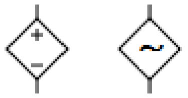
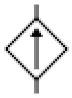
-Basic Electric Component
- -Active Component

-Passive Component

<DEF> Active Component

Producer/Generator of signal power(訊號能量)

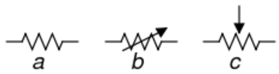
-Signal type

	Voltage	Current	
independent	 +/-: DC ~: AC		Signal Characteristic do not depend on other electric measurment in circuit
dependent	 +/-: DC ~: AC		------ [depend component]

<DEF> Passive Component

Consume signal power

-Resistor(R)(電阻): 能量耗損



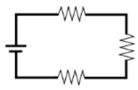
-v-i characteristic: Ohm's Law → $R = \frac{V_R}{I_R}$

-Thermal effect(熱效應): Resisters produce heat when operating

-Thermal run away

-connection:

-Serial(串聯): $R_i + R_j$

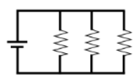


$R_{total} = \sum_{i \in Serial} R_i$

$i_i = i_j \ where \ i, j \in Serial$

$V_{total} = \sum_{i \in Serial} v_i$

-Parallel(並聯): $R_i // R_j$



$\frac{1}{R} = \sum_{i \in Parallel} \frac{1}{R_i}$

$v_i = v_j \ where \ i, j \in Parallel$

$I_{total} = \sum_{i \in Parallel} i_i$

-Capacitor(C)(電容): 位能保持與產生 +⊣ ⊢-

-Electric storage: charge(充電)/discharge(放電)

-Insulator(絕緣) medium/Air

-v-i characteristic:

$$Q_c = Cv_c(t) = \int_0^t i_c(\tau) d\tau \ \rightarrow \ v_c(t) = \frac{1}{c} \int_0^t i_c(\tau) \, d\tau \rightarrow \ i_c(t) = C \frac{dv_c(t)}{dt}$$

-C(Capacitance)(電容量), Q(電量)

-Inductance(L)(電感)(線圈): 動能保持與產生

-Electro-magnetic inductance(電磁感應)
-電介質/Air
-v-i characteristic:

$$i_L(t) = \frac{1}{L}\int_0^t v_L(\tau)\, d\tau \rightarrow \; v_L(t) = L\frac{di_L(t)}{dt}$$

-L(電感值)

-Dual relation of v-i characteristic: Capacitor ←→ Inductance

<CONCEPT> Linearity

Law of Superposition(疊加原理): 訊號可以由不同訊號源經疊加產生

$S(ax_1 + bx_2) = aS(x_1) + bS(x_2)$

<How to SOLVE an Electric Circuit>

-Complete/Full solution: find ALL the voltage (at each vertex) and current (through each edge) values in the circuit

-Partial Solution: find the voltage and current values at Input Node and Output Node

<DEF> Kirchhoff's Voltage & Current Law (KVL & KCL)

-KVL: Algebraic sum of all Voltage differences between the nodes in a Closed Loop of a circuit should always be ZERO

-closed loop: a path from one node back to itself without traversing any edge more than once
-node voltage as potential energy of electric charges
-Conservation of Energy(能量守恆定律)

$$\sum_{i \in Closed-Loop} v_i = 0$$

-(+v): same direction as flow voltage
(- v): opposite direction to flow voltage
-Use Rule:
- -Identify all Nodes in the circuit
  - -start with GROUND Node
  - -other end of every component is a distinct node
  - -repeat the procedure until all components have been visited and all nodes have been marked
  - -assign every node (except Ground) with a distinct node voltage
- -Identify all Loops in the circuit
  - -start with GROUND Node (or Upper-Left Node)
  - -identify a loop by traversing components connected to the previous node until going back to the original node (in clockwise direction)
  - -identify another new loop by including at least one new component until no new component can be included

-Identify voltage difference across each component

-assign Polarity(極性) which end node is positive

-start from Upper-Left Node which is likely to be the node with highest potential

-name the voltage differences using end nodes or components

-$v_{(+node)(-node)}$ or $v_{(component)}$

-write Circuit Equations using KVL

-one equation for every loop along loop circuit direction

-KCL: Algebraic sum of all Currents flow into (+ve) and out of (-ve) a node in a circuit should always be ZERO

-no electric charges shall be generated or destroyed in a circuit node

-Conservation of electric charges

$\sum_{i \in Node} i_i = 0$

-Use Rule:

-Identify all Nodes in the circuit

-Identify voltage difference across each component

-write Circuit Equations using KCL

-one equation for every node

<DEF> Open Circuit & Short Circuit

-Open Circuit(O.C.斷路)

-NULL Condition: $i_{AB} \equiv 0 \rightarrow R \rightarrow \infty$

-Short Circuit(S.C.短路)

-NULL Condition: $v_{AB} \equiv 0 \rightarrow R = 0$

-A and B are NOT distinguishable nodes $\rightarrow$ merge into one node

<CONCEPT> Equivalent Circuit(等效線路)

Simplify the process of solving EE (Linear) circuit

-Circuit Port: a Pair of distinct circuit nodes

-One Port Circuit

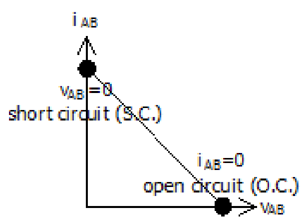
-Thevinin Equivalent Circuit: for any linear circuit, the electric characteristic (v-i characteristic) of a specific port can always be modeled as an Ideal Voltage Source (v_{th}) and a SERIALLY connected passive element with Impedance(阻抗) (Z_{th}) or Resistor (R_{th})

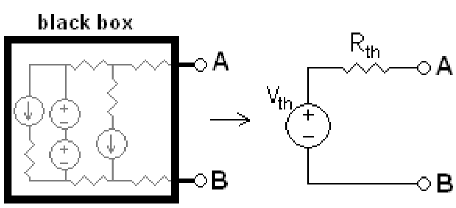
$v_{oc} \triangleq v_{AB}|_{i_{AB}=0}$; $v_{oc}(open\ circuit\ voltage)$

$i_{sc} \triangleq i_{AB}|_{v_{AB}=0}$; $i_{sc}(short\ circuit\ voltage)$

$v_{th} = v_{oc}$

$R_{th} = \frac{v_{oc}}{i_{sc}}$





-short circuit: $v_{AB}=0 \rightarrow R=0$; open circuit: $i_{AB}=0 \rightarrow R\rightarrow\infty$

KVL: (open circuit) $v_{th}-v_R(=0)-v_{AB}(=v_{oc})=0 \rightarrow v_{th}-v_{oc}=0 \rightarrow v_{th}=v_{oc}$

(short circuit) $v_{th}-v_R-v_{AB}(=0)=0 \rightarrow v_{th}=v_{oc}=v_R=R_{th}i_{sc} \rightarrow R_{th}=v_{oc}/i_{sc}$

-really practical way

-calculate v_{th}: using Voltage Divider Formula

-calculate R_{th}: estimate internal impedance

-turn off all internal signal source

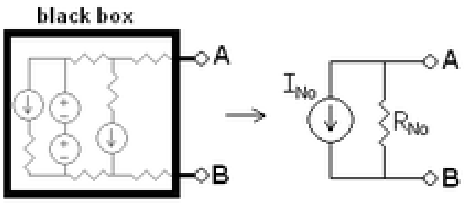
-ideal voltage source → short circuit

-ideal current source → open circuit

-Norton Equivalent Circuit: for any linear circuit, the electric characteristic (v-i characteristic) of a specific port can always be modeled as an Ideal Current Source (i_{no}) and a PARALLELY connected passive element with Admittance (Y_{no}) or Conductance(電導) (G_{no})

$i_{no} = i_{sc}$

$G_{no} = \frac{i_{sc}}{v_{oc}} = \frac{1}{R_{th}}$



<CONCEPT> Ideal Voltage/Current Source

-Ideal Voltage Source

-No internal loss

-No internal impedance/resistor → $R_{th}=0$

-Ideal Current Source

-No internal loss

-No internal admittance/conductance → $G_{no}=0$

<DEF> Transfer Function

always quantities of input vs. output signal

Four possible combinations depending on choice of input/output quantities (voltage/current)

Specify the voltage/current condition (O.C./S.C.) for measuring Transfer Function

-Voltage Ratio (Voltage Gain):

$A_v \triangleq \frac{v_{out}}{v_{in}}|_{i_{out}=0}$; (O.C.) A(amplification)

-Current Ratio (Current Gain)

$A_i \triangleq \frac{i_{out}}{i_{in}}|_{v_{out}=0}$; (S.C.)

-Trans-Resistance

$Z_T \triangleq \frac{v_{out}}{i_{in}}|_{i_{out}=0}$; (O.C.)

-Trans-Conductance

$Y_T \triangleq \frac{i_{out}}{v_{in}}|_{v_{out}=0}$; (S.C.)

<CONCEPT> Coupling(耦合)

-according to the electric characteristic of input/output signal

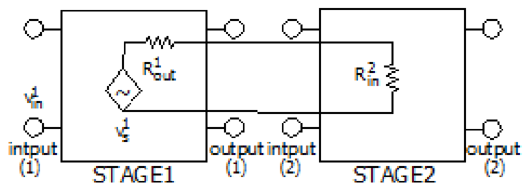
-Voltage Coupling

-Thevinin Equiv.

$v_s^1 = A_v v_{in}^1$

$v_s^1 = v_{R_{out}^1} + v_{R_{in}^2} = (R_{out}^1 + R_{in}^2)i$

$v_{in}^2 = R_{in}^2 i = \frac{R_{in}^2}{(R_{out}^1+R_{in}^2)} v_s^1 \rightarrow \frac{v_{in}^2}{R_{in}^2} = \frac{v_s^1}{(R_{out}^1+R_{in}^2)}$



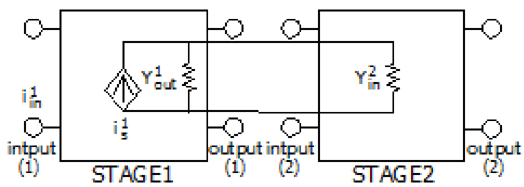
Voltage Coupling

-Current Coupling

-Norton Equiv.

$i_s^1 = A_i i_{in}^1$

$i_s^1 = i_{Y_{out}^1} + i_{Y_{in}^2} = (Y_{out}^1 + Y_{in}^2)v$



Current Coupling

$i_{in}^2 = Y_{in}^2 v = \frac{Y_{in}^2}{(Y_{out}^1+Y_{in}^2)} i_s^1 \rightarrow \frac{i_{in}^2}{Y_{in}^2} = \frac{i_s^1}{(Y_{out}^1+Y_{in}^2)}$

-according to the characteristic of transferred signal

-DC Coupling: including DC and AC component

-AC Coupling: including AC component only

-Coupling Capacitor(耦合電容) filter out the output DC components

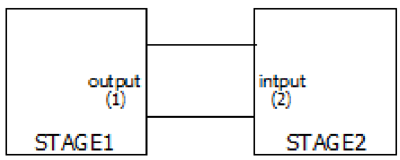
-if DC signal

$v_c(t) = v_{DC}\left(1 - e^{-t/\tau}\right)$; $\tau = R_L C$

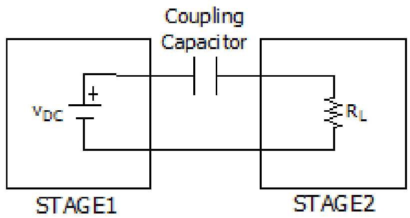
$i_c(t) = \frac{v_{DC}}{R_L}\left(e^{-t/\tau}\right)$; $\tau = R_L C$

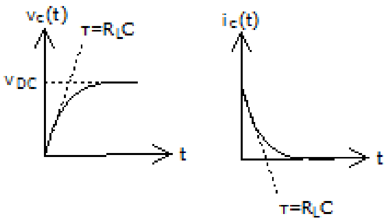
-KVL: $v_{DC}-v_C-v_L=0 \rightarrow v_L=v_{DC}-v_C$

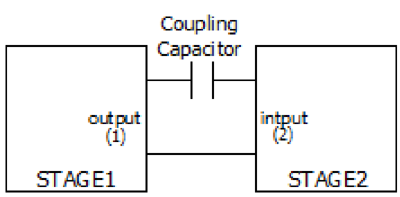
when $t\rightarrow\infty \rightarrow v_c\rightarrow v_{DC} \rightarrow v_L\rightarrow 0$



Direct Coupling (DC)







Indirect Coupling (AC)