EIE2100 cheat sheet

C1. free electrons? { Conductor ✓ / Insulator ✗

Resistance $(R) = \frac{\rho L}{A} (\Omega)$

Conductivity $(G) = \frac{1}{R}$ (℧)(or S) mho siemens

resistor { Wirewound / Composite (carbon film)

variable resistor: potentiometer (abbr. pot)
3 terminal, middle: sliding contact/wiper

C2. DC circuit only { const. V src. / const. I src. / resistors

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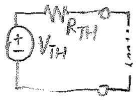
C3. { branch: connected to 2 nodes of a circuit / node: / loop: any closed path in a network / (essential) mesh = a loop that cannot be devided into smaller

analysis { ① Mesh-current Method: use KVL, get currents, V↑⊖, V↓⊕ / ② Node-Voltage Method: Use KCL, get voltages, Iout ⊕, Iin ⊖ / ③ Superposition theorem: sepatately compute; Power source

circuit simplification (focus on ext. behavior) {

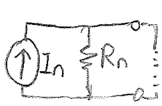
Thévenin theorem →



V_{TH} = remove load; R_{TH} = remove power source. (⊕: short, ⓘ: break)

If contain dependent source: V_{TH} = remove load; R_{TH} = remove const. source, add assistive source on load

Norton theorem →

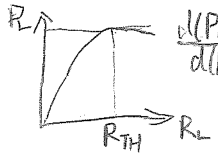


I_n: short-circuit load R_{TH} = remove power source.

Max. Power Transfer

$I = \frac{V_{TH}}{R_{TH}+R_L}$

$P_L = I^2 R_L = \frac{V_{TH}^2 R_L}{(R_s+R_L)^2} = \frac{V_{TH}^2 R_L}{(R_s-R_L)^2+4R_sR_L} = \frac{V_{TH}^2}{\left(\frac{R_s}{\sqrt{R_L}}-\sqrt{R_L}\right)^2+4R_s}$ $(R_s = R_{TL})$



$\frac{d(P_L)}{d(R_L)} = \frac{V_{TH}^2(R_{TH}-R_L)}{(R_{TH}+R_L)^3}$

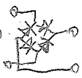
$\begin{vmatrix}1&2&3\\7&8&9\\6&5&2\end{vmatrix}$ 12 $\begin{vmatrix}1&2&3\\4&5&6\\6&5&2\end{vmatrix}$ 6 $\begin{vmatrix}A&B&C\\D&X&Y\\M&M&M\end{vmatrix}$?→M: MBY−MXC; ?→M: Ans+MCD−MAY; ?→M: Ans+MAX−MBD

C4. capacitor: store energy in the electric field between "⊥"

capacitance: Farad (F)

symbol: ⊥ ⊥ ⊥ ⊥ ⊥

type	[pro]	[cons]	[made]
polystyrene ~ 聚苯乙烯	high precision (1%~2%), high isolation (with its size) (30V~630V). Low DC leakage. Suitable for timing, tuning, analog filter	Small C, coil structure (high L). Not suitable for high f app.	2 foil separated by a thin plastic film, then roll up. 10pF ~ 1mF
Ceramic ~ 陶瓷	Rela. high C (with its size). No coil structure (low L). Suitable for high f app.	C not so high as elec. Not suitable for E storage.	Alternate layer of metal & ceramic. 1nF~1μF
Electrolytic ~ 电解	High C. Suitable for energy storage & power app.	High DC leakage (can get hot). Low precision. (can't use in timing/filtering. Have polarity. Not suit for AC.	2 Al foil separated by paper (soaked in electrolyte (Insulator = thin oxide layer on one of the foils). 1nF ~ 10mF

app. {
- electronic circuit { Freq filter (with R&L, to filter certain f) / Noice removed
- power electronic { AC to DC rectifier (shape the DC from ) / flash lamp on camera
- large electrical sys { Power factor converter

Inductor: store energy in the magnetic field in ⌇⌇⌇

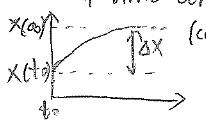
Inductance: Henry (H) symbol: air core, Iron core, ferrite ~, variable core; Shield, Surface mound inductor 贴片电感 (surface), Toroidal core

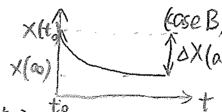
app {
- electronic circuit { freq. filter / Temperary power sourse. (store E in Mag. field) eg. octopus
- power electronic { power choke (choke high f AC, pass low f AC/DC)
- large electrical sys { transformer

 $Q = VC, \Rightarrow i = C\frac{dv}{dt}$ (KCL) $\tau = RC$

 $V_L = L\frac{di}{dt}$ (KVL) $\tau = L/R$

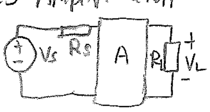
Universal time constant method:





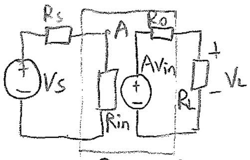
$x(t) = x(t_0) + \Delta x(1-e^{-\frac{t-t_0}{\tau}})$ $x(t) = x(\infty) + \Delta x e^{-\frac{t-t_0}{\tau}}$

C5 Amplification



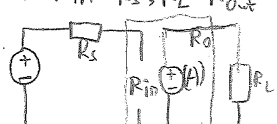
$V_L = AV_s$ A: gain (amp. factor)

Real ⟹



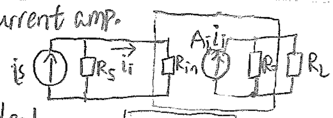
$V_L = \frac{R_L}{R_o+R_L} \times \frac{R_{in}}{R_s+R_{in}} \times AV_s$

Ideal: $R_{in} \gg R_s$, $R_L \gg R_{out}$

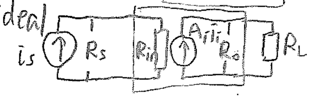


Ideal Volt. Amp { $A = \infty$ / $R_{in} = \infty$ / $R_o = 0$ / Bandw = ∞ / $V_o = 0$ for $V^+ = V^-$ (0 input offset V)

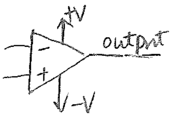
Current amp.



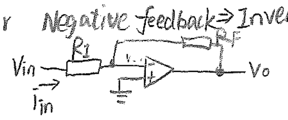
ideal



Op-Amp : Near ideal, signal conditioning, filtering, math ops. (use with ext. feedback components to determine operations)

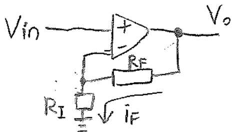
Inverting
Noninverting


Voltage follower


Negative feedback ⇒ Inverted Amp


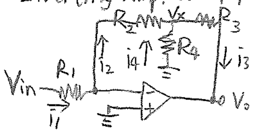
$i_{in}=\frac{V_{in}}{R_I}$ $A=-\frac{R_F}{R_I}$

$V_o=0-R_F i_{in}=-\frac{R_F}{R_I}V_{in}$

Non-Inverting Amplifier


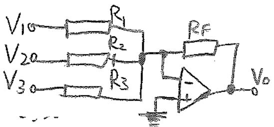
$i_F=\frac{V_{in}}{R_I}$ $A=\left(1+\frac{R_F}{R_I}\right)$

$V_o=V_{in}+i_F R_F=\left(1+\frac{R_F}{R_I}\right)V_{in}$

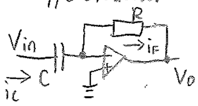
Inverting Amp. with T-Network


$i_1=\frac{V_{in}}{R_1}=i_2$ $i_4=\frac{-V_x}{R_4}=\frac{i_2R_2}{R_4}$ $A=-\frac{R_2}{R_1}\left(1+\frac{R_3}{R_4}+\frac{R_3}{R_2}\right)$

$V_x=-i_2R_2$ $V_o=-i_2R_2-(i_2+i_4)R_3=-\frac{R_2V_{in}}{R_1}\left(1+\frac{R_3}{R_4}+\frac{R_3}{R_2}\right)$

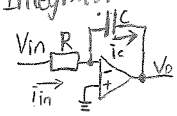
Inverting Summer


$V_o=-\frac{R_F}{R_1}V_1-\frac{R_F}{R_2}V_2-\frac{R_F}{R_3}V_3\ldots$

Differentiator


$i_C=C\frac{dv_{in}}{dt}=i_F$

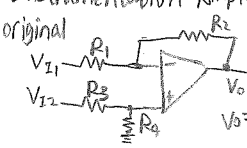
$V_o=-i_FR=-RC\frac{dv_{in}}{dt}$

Integrator


$i_{in}=\frac{V_{in}}{R}=i_C=C\frac{d(-V_o)}{dt}$

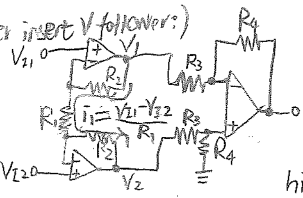
$V_o=-\frac{1}{CR}\int V_{in}\,dt$

Instrumentation Amplifier $R_2=R_3+R_4$

original


$R_i=\frac{V_{I1}}{i_1}=\frac{V_{I1}R_1}{V_{I1}-V^-}=\frac{V_{I1}R_1}{V_{I1}-V_{I2}\frac{R_4}{R_3+R_4}}=\frac{R_1}{1-\left(\frac{V_{I2}}{V_{I1}}\right)\frac{R_4}{R_3+R_4}}$

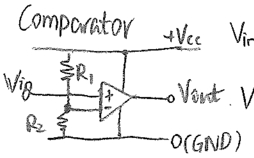
$V_o=-\frac{R_2}{R_1}V_{I1}+\frac{V_{I2}R_3}{R_3+R_4}\left(\frac{R_1+R_2}{R_1}\right),\ V_o=\frac{R_2}{R_1}(V_{I2}-V_{I1})\ \left(\text{if } \frac{R_1}{R_2}=\frac{R_3}{R_4}\right)$

(after insert V follower:)


$V_1=V_{I1}+\frac{R_2(V_{I1}-V_{I2})}{R_1}$ $V_2=V_{I2}-\frac{R_2(V_{I1}-V_{I2})}{R_1}$

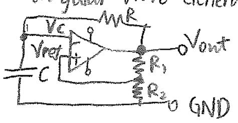
$V_o=\frac{R_4}{R_3}(V_2-V_1)=\frac{R_4}{R_3}\left(1+\frac{2R_2}{R_1}\right)(V_{I2}-V_{I1})$

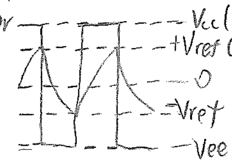
R_4 won't have to be that large to have large gain; low offset voltage ; $R_i=R_2=\infty$; (low noice) ; high CMRR (common mode rejection ratio)

Comporator


$V_{in}>\frac{R_2V_{cc}}{R_1+R_2}$: $V_{out}=V_{cc}$

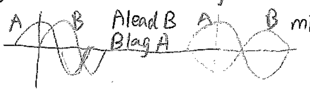
$V_{in}<\frac{R_2V_{cc}}{R_1+R_2}$: $V_{out}=0=V_{ee}$

Rectangular Wave Generator




$T=2RC\ln\left(1+\frac{2R_2}{R_1}\right)$

C6. AC: V alternating in polarity { electric generator, motor, power distribution system for more efficient than DC (power loss I^2R, $P=VI\Rightarrow I\downarrow V\uparrow$)
predominantly used in high power app.



Newly: HVDC (solid-state power electronic, DC-AC/AC-DC converter with high e)

DC ⇆ AC → HVDC → trans

AC ⇆ DC

pros. lower cable P loss; smaller power tower; less land

cons. very expensive (>800km)

C6b. Phasor $Ae^{j\varphi}=A(\cos\varphi+j\sin\varphi)\Rightarrow Ae^{j(\omega t+\theta)}=A(\cos(\omega t+\theta)+j\sin(\omega t+\theta))$ Phasor: $Ae^{j\theta}$

let $x=A\cos(\omega t+\theta)$, $\bar{X}=Ae^{j\theta}$

$X'=Re\left(Ae^{j(\omega t+\theta)}\right)'=A\omega\cos(\omega t+\theta+\frac{\pi}{2})$

$\bar{X}'=A\omega e^{j(\theta+\frac{\pi}{2})}=jA\omega e^{j\theta}=j\omega\bar{X}$

for inductor:

$V_L=L\frac{di}{dt}=\omega LI(t+\frac{\pi}{2})$

$\bar{V_L}=j\omega L\bar{I}=j\omega\bar{V}$ (delay I, lead V)

let $\sim=\frac{A}{\omega}\cos(\omega t+\theta-\frac{\pi}{2})$

$\int x\,dt=Re\left(\int Ae^{j(\omega t+\theta)}dt\right)$

$\int\bar{X}=\frac{A}{\omega}e^{j(\theta-\frac{\pi}{2})}=-\frac{jA}{\omega}e^{j\theta}=\frac{-j\bar{X}}{\omega}=\frac{\bar{X}}{j\omega}$

for capacitor:

$i(t)=C\frac{dv_c}{dt}$ $\frac{1}{C}\int i(t)=V_c$

$\bar{V_c}=\frac{1}{C\omega}\bar{I_c}(\theta-\frac{\pi}{2})=\frac{\bar{I_c}}{jC\omega}$ (delay V)

Impedence: $\bar{Z}=\frac{\bar{V}}{\bar{I}}=R+jX$ (Resistance, Reactance)

Admittance: $\bar{Y}=\frac{1}{\bar{Z}}$

Inductor: $\bar{Z}=\frac{\bar{V}}{\bar{I}}=j\omega L$

Resistor: $\bar{Z}=\frac{\bar{V}}{\bar{I}}=R$

Capacitor: $\bar{Z}=\frac{\bar{V}}{\bar{I}}=\frac{1}{j\omega C}=-\frac{j}{\omega C}$

$V(t)=I_{max}\sin(\omega t)$

$P(t)=\frac{V_{max}I_{max}}{2}\sin(2\omega t)$

N/A

$V(t)=-I_m\sin(\omega t)$

$P(t)=-\frac{V_mI_m}{2}\sin(2\omega t)$

Power { reactive [$VAR_{reactive}$] $=I_{rms}^2X$
true ~ [W] $=I_{rms}^2R$
apparent [VA] $=I_{rms}^2|Z|$

power factor $=\cos\theta$

to correct: C should be parallel with inductive load, for: { voltage drops need to break the circuit; short circuit lead to blow of them

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C7. transformer: 2 magnetically coupled inductors, for AC voltage step up/down, circuit isolation, impedance matching

Impedance transformation eg. audio transformer for impedance matching & galvanic isolation