Amplifiers

NoteBook

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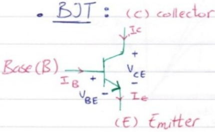
POWER UNIT
ELECTRICAL ENGINEERING

18-2/2014
Tue

* Transistor: BJT & FET

- BJT:



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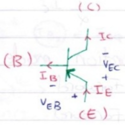

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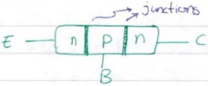

* Mode of operation for BJT:-

1. Forword - active mode ((or active region))
   BE: Forword - biased
   BC: Reverse - biased
   → BJT is used as Amplifier.

- $V_{BE} = V_{BE(ON)} = 0.7V$
- $V_{CE} > V_{CE(sat)}$ where $V_{CE}(sat) \approx 0.2v$ or $0.3v$
- $I_c = \beta I_B$, β: Gain [unit less] → at acertain tempreture, charateristic of the transistor

- $50 < \beta < 300$
- $I_E = (1+\beta) I_B$

$I_E = \frac{1}{\alpha} I_C$

2. Saturation mode :-

BE : Forword

BC : Forword

BJT is used as a switch.

- $V_{BE} = 0.7V$
- $V_{CE} = V_{CE}(sat)$
- $I_C < \beta I_B$

3. Inverse-active mode.

BE : reversed - biased

BC : forword - biased

4. Cutoff mode:

BE : reverse

BC : reverse

$I_C = I_B = I_E = 0$

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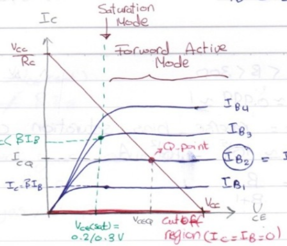
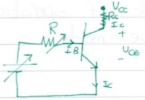


* DC- load line ($I_C \propto V_{cc}$)

$-V_{cc} + I_C R_c + V_{ce} = 0$

$I_c = \frac{V_{cc}}{R_c} - \frac{V_{ce}}{R_c}$



* V_T : Thermal voltage ($V_T = 0.026$) at room temprature 300°k

- $50 < \beta < 300$
- $\alpha \simeq 0.999 \simeq 1$
- I_s = reverse - bias saturation current
  $\simeq 10^{-15} - 10^{-12}$ A
- $\alpha = \frac{\beta}{\beta+1}$

* DC analysis of BJT :-
  → Finding the mode of operation.
  → DC load line.
  → Finding the relation between V_o & V_I.
  → DC analysis of multi-stage circuit.

- Steps for finding the mode of operation.

① Assume Forword - active mode
→ $V_{BE} = 0.7$
→ $I_C = \beta I_B$

② check your assumption
→ $I_B > 0$ and $V_{CE} > V_{CE}$ (sat), if yes stop

③ otherwise assume saturation mode
→ $V_{BE} = 0.7$

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→ $V_{CE} = V_{CE(sat)}$

$I_C \neq \beta I_B$

④ check your assumption

$I_C < \beta I_B$

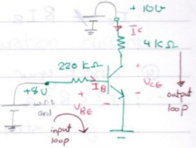
if yes, stop

⑤ otherwise, cut off mode.

Ex:- consider the following cct:-

Given : $\beta = 100$, $V_{BE(ON)} = 0.7\ V$

$V_{CE}(sat) = 0.2\ V$



npn.

1. Find the mode of operation

- assume F.A.M. → I_C معروف من I_B
  أما الـ V_C غير معروف

$V_{BE} = 0.7$

$I_C = \beta I_B$

{ input loop → I_B → I_C
{ output loop →

→ input loop:

$-8 + 220\ I_B + 0.7 = 0$

$I_B = \dfrac{8 - 0.7}{220} = 33.2\ \mu A > 0\ ✓$

$I_C = \beta I_B = 100 * 33.2\ \mu A = 3.32\ mA$

→ output loop:

$-10 + 4 * 3.32 + V_{CE} = 0$

$V_{CE} = 10 - 4 * 3.32 = -3.28\ V \overset{?}{>} V_{CE}(sat)$

No , incorrect assumption.

- assume saturation mode → V_C → معروف
  بس الـ I_C غير معروف

$V_{BE} = 0.7\ V$

$V_{CE} = V_{CE}(sat) = 0.2V$

→ input loop → $I_B = 33.2\ \mu A$

→ output loop:-

$-10 + 4 I_c + 0.2 = 0$

$I_c = 2.45 \text{ mA}$

check : $I_c \overset{?}{<} \beta I_B$

$2.45 < 3.32$ ✓

yes, Saturation Mode

2. Find Q-point values:-

Q-point values: $I_{BQ} = 3.32 \text{ mA}$

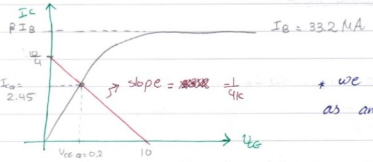
$I_{CQ} = 2.45 \text{ mA}$

$V_{CEQ} = 0.2 \text{ v}$

3. Find and draw the DC load line:-

$-10 + 4 I_c + V_{CE} = 0$

$I_c = \frac{10}{4} - \frac{1}{4} V_{CE}$ [mA] → DC-load line.



* we cant use it as amplifier.

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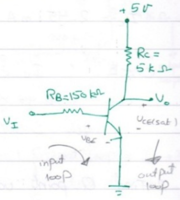
* **Ex** * Draw the voltage transfer curves ($V_o \propto V_I$) for the following cct :-



Given:

$V_{BE(ON)} = 0.7\ V$

$V_{CE}(sat) = 0.2\ V$

$\beta = 120$

- cutoff :-

$I_C = I_B = I_E = 0$

$\rightarrow V_o = 5\ V$ (V_I بغض النظر عن قيمة)

- saturation:-

$V_{CE}(sat) = 0.2$

$\rightarrow V_o = 0.2\ V$

- Forward active mode :-

$V_{BE} = 0.7$

$I_C = \beta I_B$

$\rightarrow$ input loop: $-V_I + 150\, I_B + 0.7 = 0$

$$I_B = \frac{V_I - 0.7}{150}$$

$\rightarrow$ output loop: $-5 + 5 I_C + V_o = 0$

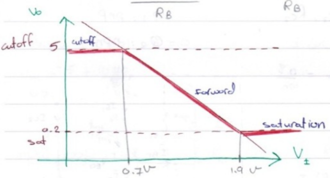
$$I_C = \frac{5 - V_o}{5}$$

$\Rightarrow \quad I_C = \beta I_B$

$$\frac{5 - V_o}{5} = 120 \left(\frac{V_I - 0.7}{150} \right)$$

$$V_o = 5 - 120 \frac{R_C}{R_B} V_I + \frac{120 R_C * 0.7}{R_B}$$

$$V_o = 5 + \frac{120 R_C * 0.7}{R_B} - \frac{120 R_C}{R_B} V_I$$ "negative slope"



في تكون pnp بالعكس

ويكون ذلك ال slope.

1

• Example :-

- input loop then output loop
- use thevenin ...

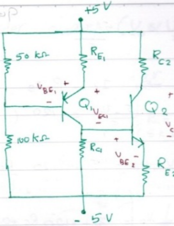
Given:-

$\beta = 100$ for both Q_1 & Q_2

$I_{C_1} = I_{C_2} = 0.8\ mA$

$V_{EB_1} = V_{BE_2} = 0.7\ V$

$V_{EC_1} = 3.5\ V$, $V_{CE2} = 4V \Rightarrow Q_1$ & Q_2 are in F.A.M



Q_1 : pnp

Q_2 : npn

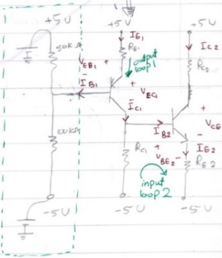
• Find R_{E_1} , R_{C_1} , R_{E_2} , R_{C_2}

$\Rightarrow I_{B_1} = I_{B_2} = \frac{I_{C_1}}{B} = \frac{0.8}{100}$

$I_{B_{1,2}} = 8\ \mu A$

$\Rightarrow I_{E_1} = I_{E_2} = (1+\beta)\ I_{B_1}$

$I_{E_{1,2}} = 0.808\ mA$



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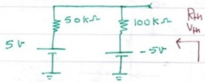

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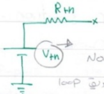
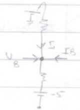


• إما بنستخدم Nodal analysis

• أو بنحسب عن طريق loop السيار و $\frac{V}{src}+\frac{V}{100\Omega}=V_{th}$

- $R_{th} = 50 \,//\, 100 = \frac{5000}{150} = 33.3\ K\Omega$



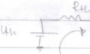
- $-5 + 50I + 100I + -5 = 0$

$I = \frac{10}{150}$ mA

$\rightarrow -V_{th} + I(100) - 5 = 0$

$V_{th} = -5 + \frac{1000}{150}$

ثم بنستبدل الجزء السابق بـ



input loop 1 :- $-5 + I_{E_1} R_{E_1} + 0.7 + I_{B_1} R_{th} + V_{th} = 0 \Rightarrow \boxed{R_{E_1} = 2.93\,k\Omega}$

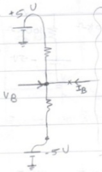
output loop 1 :- $-5 + I_{E_1} R_{E_1} + V_{EC} + R_{C_1}(I_{C_1} - I_{B_2}) - 5 = 0 \Rightarrow \boxed{R_{C_1} = 5.215\ k\Omega}$

input loop 2 :- $-(-5) - R_{C_1}(I_{C_1} - I_{B_1}) + V_{BE2} + I_{E2} R_{E2} - 5 = 0 \Rightarrow \boxed{R_{E2} = 4.25\ k\Omega}$

output loop 2 :- $-5 + I_C R_{C_2} + V_{CE2} + R_{E2} I_{E2} - 5 = 0 \Rightarrow \boxed{R_{C_2} = 3.215\ k\Omega}$

3

another solution:- "without V_{th}"



$$I_1 = \frac{5 - V_B}{50}$$

$$I_1 + I_{B_1} = \frac{V_B - (-5)}{100}$$

$$\frac{V - V_B}{50} + I_{B_1} = \frac{V_B + 5}{100}$$

$\rightarrow V_B = \ldots$

input loop:-

$$-5 + I_{E_1} R_{E_1} + V_{EB} + V_B = 0$$

Biasing → control the Q-point position

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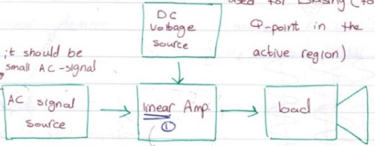
• Basic BJT Amplifier :-

used for Biasing (② to set the Q-point in the Forword active region)

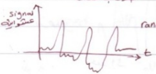
③ ; it should be small AC-signal



e.g: microphone
CD player
صوت إنسان

we can apply super position.
& DC-analysis قبل AC-analysis → (DC-analysis لمن نعمل kill to AC-srcs نعمل ولفش الشي العكس)

speacker

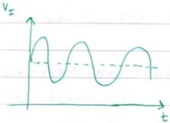


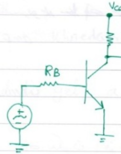
random → صعب أعمل عليها Design وآشيها as a f'n. ⇒ we sin signal → بدلاً من ال Random signal نقسمها إلى sin.. + sin+...

linear amp → output = const * Input

الفرق بين ال O/I بس const مضروب بال Input

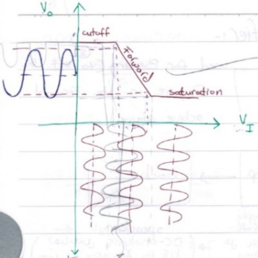
1. The transistor in Amplifier circuit should be in the forword-active Region. why ?!

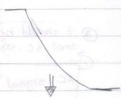




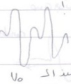
$V_I = 3 + 2\sin\omega t$

$\boxed{5}$





يصير جزء يتغير بمقدار من جهة
ومن الجهة الثانية بيتغير بمقدار
ثاني !
بتصير



عند ال V_o

لانه غيرنا مكان ال Q-point
فجزء من ال signal
رح يطلع عند منطقة ال cutoff
لهيك ما بيتغير بصير من تحت
مثلا بس حسب الموقع !

- في حالة ال Saturation & cutoff تكون V_o ← ثابت
- اما في Forward active Mode يوجد علاقة خطية ← لهيك بقدر اعمل ال amplification لل signal.
- لازم تكون Linear Relationship
- بناخذ small - AC-signal لانه تكون أقرب لل linear

أقرب لل linear

1

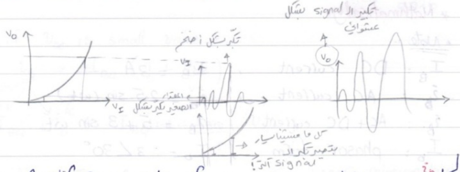
2. we need a linear amplifier, why?

⇒ linear element :- resistor, capacitor, inductor

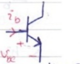
$I \propto V$ is linear.

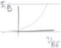
⇒ linear circuit :- all its components are linear.

⇒ linear Amplifier :- means that the Relation between V_I and V_o is linear. " to get linear amplifier we need all its components to be linear.



• Amplifier consists of : resistor, capacitor, transistor
linear, linear, non-linear





3. we need small AC-signal to get a linear transistor. How?

→

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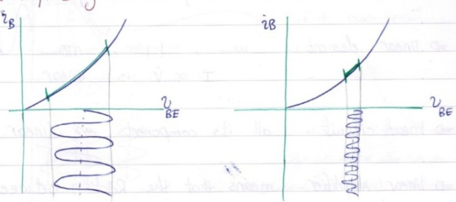
* Graphically :-



* Mathmatically:-

* Note :-

I_B : DC current , $I_B = 3A$

i_b : AC current , $i_b = 2.5 \sin(\omega t)$

i_B : AC + DC current , $i_B = 5 + 3 \sin \omega t$

I_b : phasor form , $I_b = 3\angle 30^\circ$

Reverse saturation current is

→ We know that $i_B = \frac{I_s}{1+\beta} \exp\left(\frac{v_{BE}}{V_T}\right)$

$$= \frac{I_s}{1+\beta} \exp\left(\frac{V_{BEQ} + v_{be}}{V_T}\right)$$

$$\rightarrow i_B = \underbrace{\frac{I_s}{1+\beta} \exp\left(\frac{V_{BEQ}}{V_T}\right)}_{I_{BQ}} \cdot \exp\left(\frac{v_{be}}{V_T}\right)$$

(3)

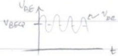
$\therefore\ i_B = I_{BQ} \cdot \exp\left(\frac{v_{be}}{V_T}\right)$

Note:-

Taylor Series : $e^{\theta} = \frac{\theta^0}{0!} + \frac{\theta^1}{1!} + \frac{\theta^2}{2!} + \frac{\theta^3}{3!} + \cdots$

if $\theta \ll 1 \Rightarrow e^{\theta} \simeq 1 + \theta$ — تحول ال exponential Relationship الى linear Relationship.

$\Rightarrow e^{\frac{v_{be}}{V_T}} \simeq 1 + \frac{v_{be}}{V_T}$ if $\frac{v_{be}}{V_T} \ll 1$



$V_{be} \ll \underset{0.026}{V_T}$

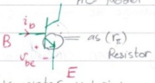
if v_{be} is small value :-

$\underset{\text{جزئين}}{i_B} \simeq I_{BQ}\left(1 + \frac{v_{be}}{V_T}\right)$

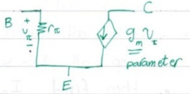
$\underset{\text{جزء DC}}{\cancel{I_{BQ}}} + \underset{\text{جزء AC}}{i_b} \simeq \cancel{I_{BQ}} + \frac{I_{BQ}}{V_T} v_{be}$

$i_b = \underbrace{\frac{I_{BQ}}{V_T}}_{\text{const}} v_{be} \Rightarrow$ So linear relationship

AC Model



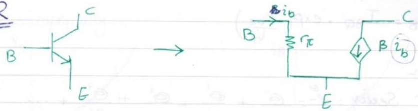
$\Rightarrow$ $\therefore$ small signal Hybrid - π equivalent cct.



نستبدل ال transistor ب linear cct

#4

OR



- $r_\pi = \dfrac{V_T}{I_{BQ}}$ " diffusion resistance " $[\Omega]$
- $g_m = \dfrac{I_{CQ}}{V_T}$ " transconductance " A/V $[\mho]$
- $r_\pi \times g_m = \beta$

*procedure: DC-anlaysis then AC-analysic *

H-parameter Model : X. غير مطلوب

* General steps to Solve an Amplifier circuit :-

① DC-analysis :-

- Draw DC-equivalent cct
  - kill all AC-sources < current src —o o— O.C ; voltage src ——— S.C
  - replace all capacitors by open circuit سندرسها — m
    بـ S.C بس عارع نترمعنا
  - keep all DC-sources.
- then find I_{BQ}, I_{CQ}, V_{CEQ}

② AC- analysis :-

- Draw the AC-equivalent cct :-

1- Replace the transistor by the Hybrid - π equivalent c

2- kill all DC-sources

3- Replace all capacitor by short-circuit

- Find voltage gain $A_v = \frac{v_o}{v_I}$

i_b , i_c , v_{ce} , R_i , R_o

4- then by using super position :-

find result = AC + DC

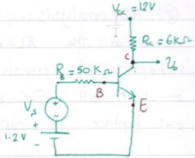
$i_B = i_b + I_{BQ}$

* Ex * 6.1

$\beta = 100$, $v_{BE(ON)} = 0.7\ v$

Find the voltage gain

$A_v = \dfrac{v_o}{v_s}$



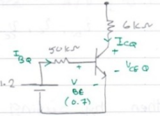
$V_s = 0.25 \sin \omega t$

not apractical amp.cct

- DC-analysis :-

⇝ DC equivalent cct :-

∴ input loop:-



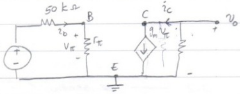
$-1.2 + I_{BQ}(50) + 0.7 = 0$

$I_{BQ} = 10\ \mu A$

∴ $I_{CQ} = \beta I_{BQ} = 1\ mA$.

- AC-analysis :-

⇝ AC-equivalent cct :-



$A_v = \dfrac{v_o}{V_s}$

→ $v_o = -g_m v_\pi R_c \rightarrow \boxed{1}$

$v_\pi = v_s \dfrac{r_\pi}{r_\pi + R_B} \rightarrow \boxed{2}$

Sub (2) in (1):-

$$v_o = -g_m R_c * \frac{v_s r_\pi}{r_\pi + R_B}$$

$$\therefore A_v = \frac{v_o}{v_s} = \frac{-g_m R_c r_\pi}{r_\pi + R_B}$$

$$\cdot\ r_\pi = \frac{V_T}{I_{BQ}} = \frac{0.026}{10 \times 10^{-6}} = 2.6\ k\Omega$$

$$\rightarrow g_m = \frac{I_{CQ}}{V_T} = 38.5\ mA/V$$

$$\boxed{A_v = -11.4}$$

-ve sign:- phase shift = 180° between V_s and V_o

Find and Draw i_B, i_c, v_{CE} if $v_s = 0.25 \sin wt$
DC & AC

From AC-cct

$$i_B = i_b + I_{BQ}$$

$$i_B = \frac{v_s}{50 + r_\pi} + 10\ M$$

$$i_B = \frac{0.25 \sin wt}{50 + 2.6} + 10\ M$$

$$i_B = 4.75 \sin wt_m + 10\ M$$

$i_C = i_c + I_{CQ}$

$i_C = \beta i_b + I_{CQ}$

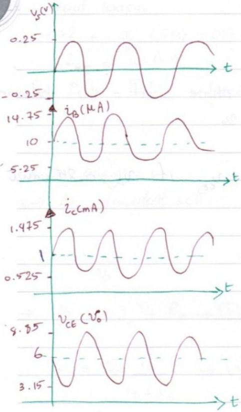
$i_C = 0.475 \sin \omega t + 1 \, mA$

$v_{CE} = v_{ce} + V_{CEQ}$

$v_{CE} = -i_c R_c + 12 - I_{CQ} * 6$

$v_{CE} = -2.85 \sin \omega t + 6 \, v$

where $v_{ce} = v_o$

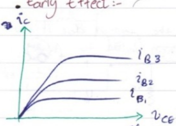


Because theres diffrent units

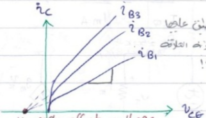
* Hybrid π - equivalent model including the Early Effect:

π شكله زي !

• Early Effect :-

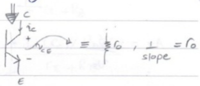


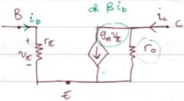
without early effect



with early effect

كأنه انطبق عليها قانون أوم لأنه العلاقة اصبحت خطية!





→ the AC- equivalent with early effect.

* early effect → r_o parallel to ◇

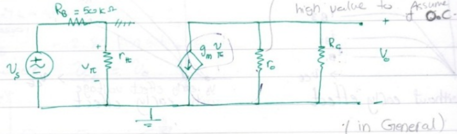
* $r_o = \frac{V_A}{I_{CQ}}$

* the early effect reduce the gain voltage.

4-3-2014 Tue.

Ex:- consider the last example:-
Find $A_v = \frac{v_o}{v_I}$, if $V_A = 50\,V$.

$$r_o = \frac{V_A}{I_{CQ}} = \frac{50}{1\,mA} = 50\ k\Omega$$



$$A_v = \frac{v_o}{v_s}$$

(in General) early effect ↓ reduce / decrease the Gain

$$v_o = -g_m v_\pi (R_C // r_o) \quad \text{---- (1)}$$

$$v_\pi = v_s \frac{r_\pi}{r_\pi + R_B} \quad \text{---- (2)}$$

* اللي طالع ده حل *

Sub (2) in (1).

$$v_o = -g_m (R_C // r_o)\, v_s \frac{r_\pi}{r_\pi + R_B}$$

$$A_v = -g_m (R_C // r_o) \frac{r_\pi}{r_\pi + R_B}$$

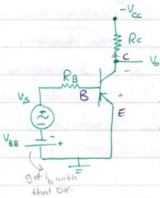
$A_v = -10.2$ The early effect reduces the Gain.

* نعكس اتجاهات الـ Biasing : npn → pnp
أما الـ ac غير مؤثرة لأنها Alternating -
فنعكس V_{cc} & V_{BB} نحصل على i تتوافق اتجاهاته
مع الاتجاهات المطلوبة

4-3-2014 Tue

* PnP - transistor :-

Acct نظير تأثير early effect



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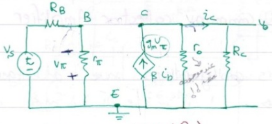


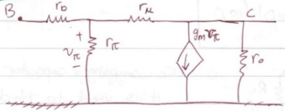
$$v_o = g_m v_\pi (r_o // R_L)$$

$$v_\pi = -v_s \frac{r_\pi}{r_\pi + R_B}$$

same as npn ← $A_v = \dfrac{-g_m (r_o // R_L)\, r_\pi}{r_\pi + R_B}$

use the Both ماحدش هيفرق ، والباقي سواء in

* Note *



$r_b \simeq 0$ → very small value → S.C

$r_\mu = \infty$ → very high value → O.S

we can negligable it.

* Basic Transistor Amplifier configuration:-

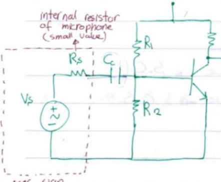
① Common Emitter Amplifier (CE) وين ال I / O مشتركين
② Common Base Amplifier (CB) والمتبقي هو ال common
③ Common collector Amplifier (CC) ← common هو الفرع الغير مسئول عن أي شي!

this configurations have advantges and Disadv... (multistage)
→ لهيك عنا أكثر من شكل!

• CE amplifier:-

1- Basic CE amplifier
2 - Basic CE amplifier with Emitter resistor
3- Basic CE amplifier with Emitter resistor and Bybass capacitor.
4 - Advanced CE amplifer

1. Basic CE Amplifier



C_c : coupling capacitor it is used to block any DC component from the user. SO, the position of Q-point is independent on the DC component from the user.

• Basic CE Amplifier :-

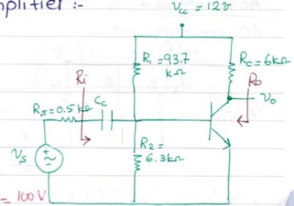
Example :-

Find : ① the voltage gain $A_v = \dfrac{v_o}{v_s}$

② R_i "input impedance"

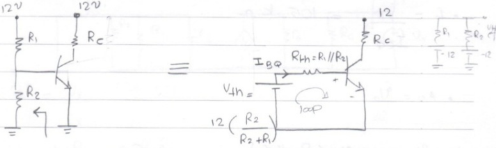
③ R_o "output impedance"

$\beta = 100$ $\quad V_{BE(ON)} = 0.7$ $\quad V_A = 100\,V$



DC analysis :-

DC equivalent cct :-



$$-V_{th} + R_{th} I_{BQ} + 0.7 = 0$$

$$I_{BQ} = 9.5\ \mu A$$

$$I_{CQ} = \beta I_{BQ} = 0.95\ mA$$

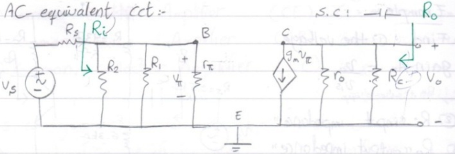
$$V_{CEQ} = 12 - I_{CQ} R_c = 6.31\ v \quad \simeq \tfrac{1}{2}(12) \rightarrow \text{Best value!}$$

Best value to get good Amplification

Gnd → 0 $\qquad \dfrac{12 - -12}{2} \qquad$ -12

AC-analysis:-

AC-equivalent cct:-



- $r_\pi = \dfrac{V_T}{I_{BQ}} = 2.74\ k\Omega$
- $g_m = \dfrac{I_{CQ}}{V_T} = 36.5\ mA/V$
- $r_o = \dfrac{V_A}{I_{CQ}} = 105\ k\Omega$
- $A_v = \dfrac{v_o}{v_s}$

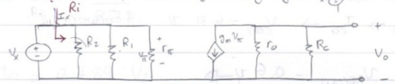
$\rightarrow$ $v_o = -g_m v_\pi (R_c // r_o) \rightarrow$ (1)

$\rightarrow$ $v_\pi = v_s \dfrac{(R_1 // R_2 // r_\pi)}{R_1 // R_2 // r_\pi + R_s} \rightarrow$ (2)

Sub (2) in (1)

$$A_v = \frac{v_o}{v_s} = \frac{-g_m (R_c // r_o)(R_1 // R_2 // r_\pi)}{(R_1 // R_2 // R_\pi) + R_s} = -163$$

to find R_i بنركب src v_x ونعمل killing لكل ال srcs ال indep

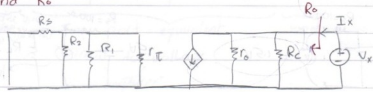


$$R_i = \frac{V_x}{I_x} \text{, using } v_{th}$$

$$-v_x + I_x (R_1 // R_2 // r_\pi) = 0$$

$$R_i = \frac{v_x}{I_x} = R_1 // R_2 // r_\pi = 1.87\ k\Omega$$

to find R_o



$$R_o = \frac{v_x}{I_x}$$

$$\Rightarrow R_o = r_o // R_c$$

$$= 5.68\ k\Omega$$

Advantage:- high A_v

Disadvantage:- 1. very sensitive to $v_{BE(ON)}$ → (unstable performance)

الحرارة تؤثر عليه

if $V_{BE(ON)} = 0.7\,V \Rightarrow$

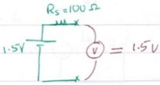
$I_{BQ} \rightarrow I_{CQ} \rightarrow V_{CEQ} = 6.31\ V$ "Forword"

if $V_{BE(ON)} = 0.6\ V \Rightarrow$

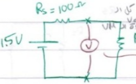
$I_{BQ} \rightarrow I_{CQ} \rightarrow V_{CEQ} = -3.6\ V$ "Not Forword"

2. high loading effect:-

loading effect:



src without load



تزداد ⇐ تأخذ كل ال voltage ⇐ فتعطي قراءة ال VM

src with load

$V = 1.5\left(\frac{500}{500+100}\right) = 1.25\ V$

$1.25 < 1.5$

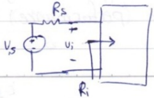
→ To reduce the loading effect ($V_o \simeq V_s$)
R_L should be $\gg R_s$

→ in our example:

$R_i = 1.87\ k\Omega$

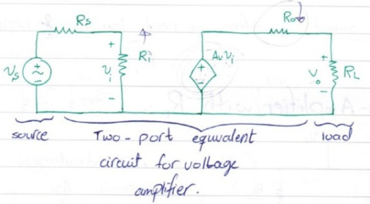
$R_s = 0.5\ k\Omega$

$R_s \lll R_i$



$$v_i = v_s \frac{R_i}{R_i + R_s}$$

$$v_i = 0.789\ V_s$$



- $v_i = v_s \dfrac{R_i}{R_i + R_s}$

To reduce the loading effect on the input circuit $(v_i \approx v_s)$ we need high R_i

- $v_o = A_v v_i \dfrac{R_L}{R_L + R_o}$

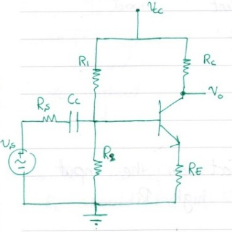
To reduce the loading effect on the output circuit ($v_o \approx A_v v_i$) we need Low $\underline{R_o}$ حتى R_L ع E ع ال voltage ل

* (High R_i and Low R_o) Good voltage Amp مواصفات ال *

* مواصفات ال Good current Amp عكس ال voltage Amp

→ For current amplifier we need low R_i & high R_o

• CE-Amplifier with R_E :-



* Disadvantage:-
small A_v
* Advantages:-
1. A_v is less dependent on β (stable gain)
2. small loading effect.

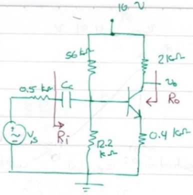
Example

$\beta = 100$, $V_A = \infty$ (no early effect, $r_o = \infty$ open cct),

$v_{BE(ON)} = 0.7\,v$

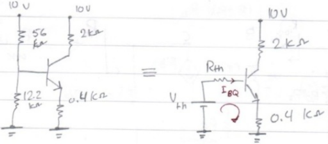
Find:-

① A_v ② R_i ③ R_o



· DC analysis:-

DC-equivalent cct:



$R_{th} = 56 // 12.2$

$\boxed{R_{th} = 10\,k\Omega}$

$\boxed{V_{th} = 1.78\ V}$

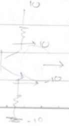
*input loop:-

$-v_{th} + R_{th} I_{BQ} + 0.7 + 0.4(1+\beta) I_{BQ} = 0$

$I_{BQ} = 0.0216\ mA = 21.6\ \mu A$

$I_{CQ} = \beta I_B = 100 \times 21.6\mu = 2.16\ mA$

$V_{CEQ} = 4.81\ V$

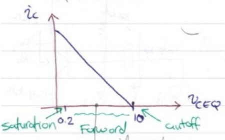


cutoff إذا ← Best value for V_{CEQ}

$I = 0$

القيم الي هون

$v_{CEQ} = 4.81\ v$



mid point

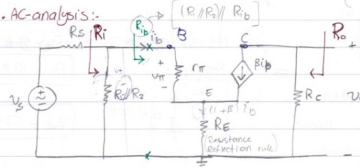
$$v_{CEQ} = \frac{10+0.2}{2} = 5.1 \quad \text{Best value for } v_{BEQ}$$

$\begin{cases} g_m v_b \to \\ \beta i_b \to \text{with } R_E \end{cases}$

مشتركة بين
ال I و O
لما يكون في R_E
use βi_b

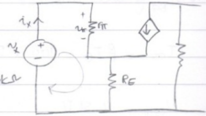
• AC-analysis:-

$R_i = (R_1 // R_2) // R_{ib}$



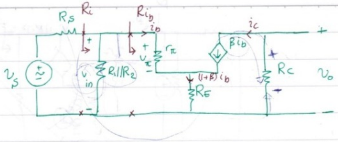
$R_{ib} = \frac{v_x}{I_x}$

$-v_x + i_x r_\pi + (1+\beta)\, i_x R_E = 0$



$R_{ib} = \frac{v_x}{i_x} = r_\pi + (1+\beta) R_E = 41.6\,k\Omega$

$\rightarrow R_i = R_1 // R_2 // R_{ib} = 8.06\ k\Omega$



$R_i = R_1 \,//\, R_2 \,//\, R_{ib}$

$R_{ib} = r_\pi + (1+\beta) R_E$

$A_v = \frac{v_o}{v_s}$

$\rightarrow v_o = -\beta i_b R_C$ — $\boxed{1}$

$v_i = v_s \frac{R_i}{R_i + R_s}$

$i_b = \frac{v_i}{R_{ib}} = v_s \frac{R_i}{R_{ib}(R_i + R_s)}$ — $\boxed{2}$

use 1 & 2:-

$A_v = \frac{v_o}{v_s} = \frac{-\beta R_C}{r_\pi + (1+\beta) R_E} \left(\frac{R_i}{R_i + R_s} \right)$

$\boxed{A_v = -4.53}$ exact value.

$r_\pi = 1.2\ k\Omega$

$1+\beta \simeq \beta$

$\frac{R_i}{R_i}$ تلغى R_s يكون ⇐ كثير من R_s > R_i

11-3/2014 Tue

approximate value of $A_v \simeq \dfrac{-R_C}{R_E}$ نقدر نستخدم المعادلة but use this in exam

Because:-

1. $(1+\beta)R_E \gg r_\pi$
2. $R_i \gg R_s$

Disadvantage:- small $A_v = -4.53$

Advantage :- 1. A_v is less dependent on β

β في البسط والمقام بيتغيروا سوا تقريباً

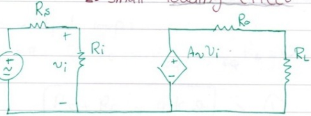
β	A_v
50	−4.41
100	−4.53
150	−4.57

A_v = stable ≃ remains constant.

مقارنة R_i بالنسبة R_s

2. small loading effect

$R_i \uparrow$ ⇐ أحسن تكون ال loading effect قليل



$v_i = v_s \dfrac{R_i}{R_i + R_s}$ $R_i \to 8.06$, $R_i + R_s \to 0.5\ k\Omega$

$v_i = 0.942\ v_s$

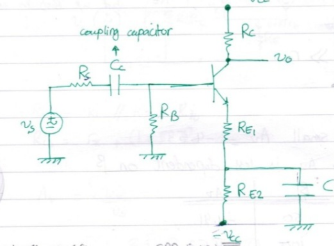
* npn OR pnp نفس الشي.

* for stability use this design CE with R_E but for the gain ⇒ multistage نبني Design

loading effect → Buffer نركب
لحل المشكلة بجعل Zero L.E بين الطرفين R_L & R_o

11-3-2014 / TUE

3. CE with R_E and By pass Capacitor:-



(S.C)

- $\uparrow A_v = \frac{-R_C}{R_E \downarrow}$ in AC
  بدي تكون قليلة
- DC analysis $R_E \uparrow$
  نحتاج انها تكون High
  → $R_E = R_{E1} + R_{E2}$
  (open cct)

C_E → By pass capacitor
• parallel with R $\langle$ R_C OR R_E

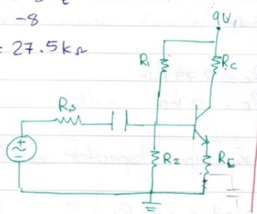
theres no src to get i_b ⇐ GRD و بالتالي $= v_{cc}$

C_E : ByPass capacitor → To satisfy the AC and DC requrement.

→ simplify Design & Analysis

Example consider a CE amplifier with R_E. Use the approximate gain $A_s = \frac{-R_c}{R_E}$, Assume that
$I_{CQ} = 1\ mA = I_{EQ}$.
$V_{CE} = 5\ V$ $\quad V_{cc} = 9\ V$
$\beta = 99$ $\quad R_1 // R_2 \approx \infty$.

Find R_c & R_E such that:
[1] $A_v = -8$
[2] $R_i = 27.5\ k\Omega$



DC requrements:
$I_{CQ} = 1mA$
$V_{CEQ} = 5V$

AC requirements.
$A_v = -8$
$R_i = 27.5\ k\Omega$

DC: output loop:

$$-9 + \underbrace{I_{CQ}}_{1mA} R_c + \underbrace{V_{CEQ}}_{5V} + \underbrace{I_{EQ}}_{1mA} R_E = 0$$

$$\boxed{R_c + R_E = 4\ k\Omega} \rightarrow (1)$$

AC: $A_v = -8 = -\frac{R_c}{R_E} \rightarrow \boxed{R_c = 8 R_E} \rightarrow (2)$

16-3/2014

$R_i = 2.75\ k\Omega$

$R_i = R_1 // R_2 // R_{ib}$

$27.5 = r_\pi + (1+\beta)R_E$

$\frac{V_T}{I_{BQ}} = 2574$

$R_E = 0.25\ k\Omega.$

From ①: $R_C = 3.75\ k\Omega$

From ②: $R_E = 2\ k\Omega$ conflict. !مشكلة

Solution:- use bypass capacitor on R_E or R_C

- Bypass capacitor on R_E:-

DC: $-9 + I_{CQ} R_C + V_{CEQ} + I_{EQ}(R_{E_1} + R_{E_2}) = 0$

$R_C + R_{E_1} + R_{E_2} = 4\ k\Omega$ .... ①

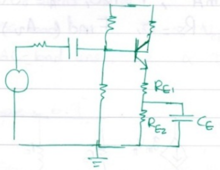
AC:- $A_V = 8 = \frac{-R_C}{R_{E_1}} \rightarrow R_C = 8 R_{E_1}$ .... ②

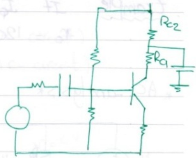
$R_i = r_\pi + (1+\beta) R_{E_1} \rightarrow R_{E_1} = 0.25\ k\Omega.$

from ②: $R_C = 2\ k\Omega$

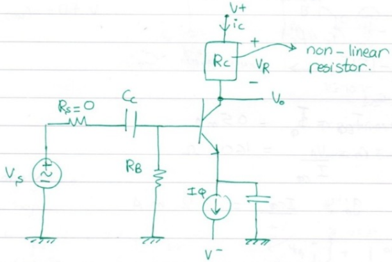
from ①: $R_{E_2} = 1.75\ k\Omega$

16-3/2014

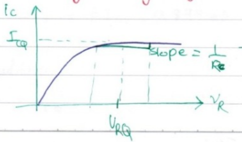




- Advanced common Emmiter amplifier CE :



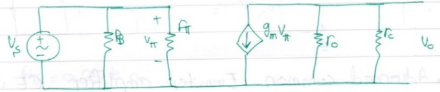
Advantage :- very high A_v



→ Very high R_c → very high A_v.

Example If $I_Q = 0.5\,mA$, $\beta = 120$, $V_A = 80V$
$r_c = 120\,k\Omega$ $R_s = 0$, Find (A_v) :-

* AC -analysis*



$A_v = -g_m\,(r_o // R_c)$
$= -1317 \rightarrow$ very high Gain.

where $I_{EQ} = \frac{I}{Q} = 0.5\,mA$

$r_o = \frac{V_A}{I_{CQ}} = 160\ \Omega$

$g_m = \frac{I_{CQ}}{V_T} = 19.2\ mA$

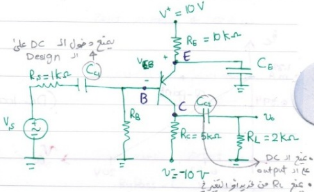
- AC- load line:-
  - DC- load line: $I_C \propto V_{CE}$ (DC- circuit)
  - AC- load line: $i_c \propto v_{ce}$ (AC- circuit)

* Example :- 6.9

$\beta = 150$

$V_A = \infty$

$V_{EB(ON)} = 0.7\ V$



pnp-transistor

common Emitter Amp.

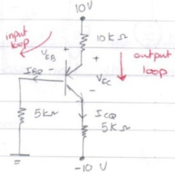
DC- analysis

input loop:-

$-10 + \underset{\overset{\downarrow}{(1+\beta)I_B}}{I_{EQ}} \times 10 + 0.7 + 5 I_{BQ} = 0$

$\rightarrow I_{BQ} = 5.96\ \mu A$

$I_{CQ} = \beta I_{BQ} = 0.894\ mA$



output loop:-

$-10 + I_{EQ} R_E + V_{ECQ} + I_{CQ} R_C - 10 = 0 \rightarrow \boxed{V_{ECQ} = 6.53V}$

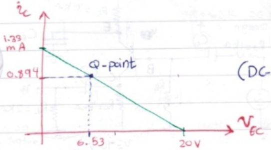
حالة ال FAM • DC- load line:-

$$-V^+ + R_E\left\{\frac{(1+\beta)}{\beta} I_c\right\} + V_{EC} + I_c R_c + V^- = 0$$

$\to I_{EQ}$

$$I_c = \frac{V^+ - V^-}{R_c + (\frac{1+\beta}{\beta})R_E} - \frac{V_{EC}}{R_c + (\frac{1+\beta}{\beta})R_E}$$

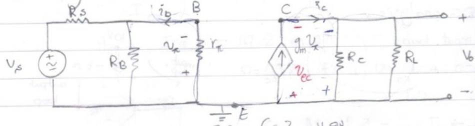
بنحكي عن ال Mode of operation
By default (in Forward)



(DC- load line)

العلاقة بين i_c مع V_{EC}

* AC- analysis *



$C_E \to$ s.c
$v^+ \to$ ground and
R_E بروح ?
وبصير ال E ع ground

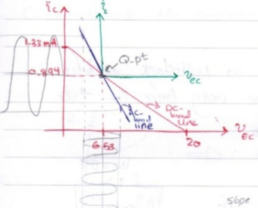
ليش ال E مشبوك ع ال ground?

* AC-load line:-

$$v_{ce} = -i_c \, (R_c \,//\, R_L)$$

$$i_c = -\frac{1}{R_c // R_L} \, v_{ec} \rightarrow \text{AC-load line eqn.}$$

من Q.pt ← نقطة ال zero



* علاقة التكبير والانعكاس بـ AC-load line.

أنه مقدار التكبير Gain

من AC-cct بناخده

* وجود ال ByPass-C

بخلي ال R_E في DC ومو في ال AC

← بتغير مقدار ال slope > slope AC / slop DC

• AC-load line helps in visualizing the relationship between the small signal response and the transistor characteristics.

* R_{ib} should be High because $R_i = R_1 // R_2 // R_{ib}$

R_i تتأثر High بالـ R_{ib} ... لازم تكون R_2 & R_1 ⇐ High

من خصائص توصيل الـ parallel

20-3-2014

* Common Collecter Amplifier:-
(Emitter follower / buffer).

* Features:-

1. High R_i → loading effect is small in the input → $V_s = V_i$
2. Low R_o → as S.C → small loading effect in the output
3. $A_v \simeq +1$
4. $A_i \simeq 1 + \beta$
5. its used as a final stage in Multistage amplifier
6. R_1 & R_2 ~~should~~ should be very large to take the advantage of high R_{ib}.

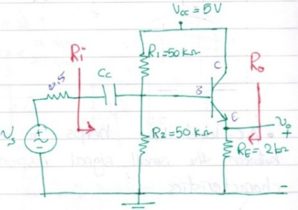
Ex

$\beta = 100$

$V_A = 80V$

Find $A_V = \frac{V_o}{V_s}$,

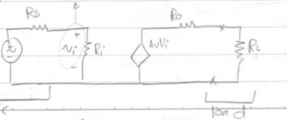
R_i, R_o, $A_i = \frac{I_o}{I_{in}}$



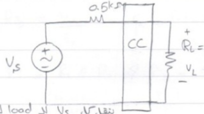
تاخذ تقريبا كل الـ V_s للـ load without Drop

$v_i = v_s \frac{R_i}{R_i + R_s}$ (1)

$v_i = v_s$ because R_i very High



توضيح:



$V_L = V_s \frac{1}{1.5}$

$V_L = \frac{2}{3} V_s$

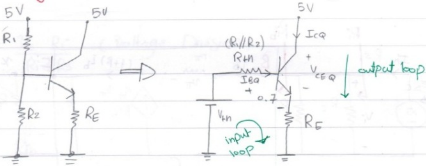
→ if we connect CC → $V_L = V_s$

ينقل كل Vs لل load لصحيح
اسمه Buffer

and the voltage in E follows the input voltage (in Mag & phase)

CC → because the common is collecter.

- Dc-analysis :-



input loop: $-2.5 + I_{BQ}(25) + 0.7 + R_E(1+\beta) I_{BQ} = 0$

$I_{BQ} = 7.929\ \mu A$

$I_{CQ} = \beta I_{BQ} = 0.793\ mA$

output loop: $-5 + V_{CEQ} + R_E I_{EQ} = 0$

$V_{CEQ} = 3.5\ V$

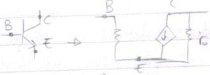
20-3-2014 Thu.

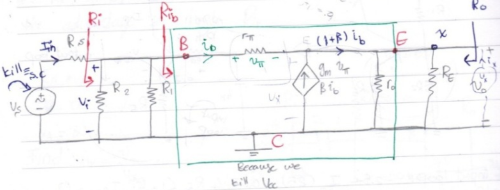
- $r_\pi = \dfrac{V_T}{I_{BQ}} = 3.28\ k\Omega$

- $g_m = \dfrac{I_{CQ}}{V_T} = 30.5\ mA/V$

- $r_o = \dfrac{V_A}{I_{CQ}} = 100\ k\Omega$

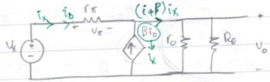
- AC-analysis:-





$R_i = R_1 // R_2 // R_{ib} \rightarrow$ نركب i_x & v_x ونستخدم R_{ib} أسهل

ارتفاع R_{ib} بالاعتماد على R_E



loop $\rightarrow -v_x + i_x r_\pi + (1+\beta) i_x (r_o // R_E) = 0$

20-3-2014. Thu

$$\therefore R_{ib} = \frac{v_x}{i_x} = r_\pi + (1+\beta)(r_o \,//\, R_E) = 201 \ k\Omega$$

$$\rightarrow R_i = \underbrace{R_1 \,//\, R_2}_{\text{should be High}} \,//\, \underbrace{R_{ib}}_{\text{High}} = 22.2 \ k\Omega$$ (High value with respect to R_s)

$$A_v = \frac{v_o}{v_s}$$ بإيجاد علاقة بين v_o & V_s

$$v_o = (1+\beta)\, i_b \,(r_o \,//\, R_E)$$

$$v_{in} = \frac{v_s \, R_i}{R_i + R_s}$$ (voltage Division)

$$i_b = \frac{v_{in}}{R_{ib}}$$

$$\rightarrow A_v = \frac{v_o}{v_s} \left(\frac{r_\pi + R_1 \,//\, R_2 \,//\, R_s}{1+\beta} \right) // \, R_E \,//\, r_o$$

$$= +0.962 \simeq 1$$

23-3/2014

$$R_o = \frac{v_x}{i_x}$$

KCL at node x:-

$$I_x + g_m v_\pi = \frac{v_x}{R_E} + \frac{v_x}{r_o} + \frac{v_x}{r_\pi + R_s // R_1 // R_2} \rightarrow (1)$$

$$v_\pi = -v_x \frac{r_\pi}{r_\pi + R_s // R_1 // R_2} \rightarrow (2)$$

sub (2) in (1):

$$R_o = \frac{v_x}{i_x}$$

$$= \left(\frac{r_\pi + (R_1 // R_2 // R_s)}{1+\beta}\right) // R_E // r_o$$ it can give a difference

$R_o = 36.6\ \Omega$ "very low value"

$$A_I = \frac{i_o}{i_{in}}$$

$$i_o = (1+\beta)\, i_b \frac{r_o}{r_o + R_E} \rightarrow (1)$$

$$i_b = i_{in} \frac{R_1 // R_2}{R_1 // R_2 + R_{ib}} \rightarrow (2)$$

$R_{ib} \rightarrow r_\pi + (1+\beta)(r_o // R_E)$

23-3/2014

use ① & ②:

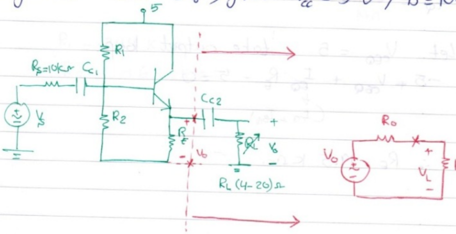
$$A_i = \frac{i_o}{i_{in}} = (1+\beta)\left(\frac{R_1 /\!/ R_2}{R_1 /\!/ R_2 + R_{ib}}\right)\left(\frac{r_o}{r_o + R_E}\right)$$

Typically/usually $r_o \gg R_E$ $r_o = 100\,k\Omega$, $R_E = 2\,k\Omega$

$R_1 /\!/ R_2 \gg R_{ib}$ in this ex. isn't typical

$\rightarrow A_i \simeq 1+\beta \simeq \beta$

Example :- Design a common collector amp. (CC) that connects a voltage source (microphone) with $R_s = 10\,k\Omega$ with a load that has R_L changes from $4\,k\Omega$ to $20\,k\Omega$, we want to design CC amplifier such that the output voltage doesn't vary more than 5%, given $V_{cc} = 5\,V$ / $\beta = 100$



$0.95\, v_o \leq v_L \leq v_o$

$0.95\, V_o = V_o \frac{R_L}{R_L + R_o} \Rightarrow R_o = 200\ \Omega$

at $R_L = 4k\Omega$ (cause it will give the least v_L)

- For CC:

$R_o = \left(\frac{r_\pi + R_1 // R_2 // R_s}{1+\beta} \right) // R_E // r_o$

usually $R_1 // R_2 \gg R_s$

$\frac{r_\pi + R_1 // R_2 // R_s}{1+\beta} \ll R_E // r_o$

$\Big\} \; R_o \simeq \frac{r_\pi + R_s}{1+\beta}$

$r_\pi = 10.2\ k\Omega$

$r_\pi \simeq \frac{V_T}{I_{BQ}} \rightarrow I_{BQ} = \frac{0.026}{10.2k} \simeq 2.55\ \mu A$

$I_{CQ} = 0.255\ mA.$

let $V_{CEQ} = 5$, take output loop:

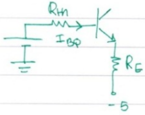
$-5 + V_{CEQ} + \underset{\underset{(I_{CQ} + I_{BQ})}{\downarrow}}{I_{EQ}} R_E - 5 = 0$

$\therefore R_E = 19.5\ k\Omega.$

23-3/2014

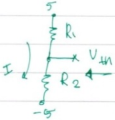
→ For stability $R_{th} = 0.1(1+\beta)R_E$ "Rule"

$R_{th} (= R_1 // R_2) = 198\ k\Omega$



$-V_{th} + R_{th} I_{BQ} + 0.7 + I_{EQ} R_E - 5 = 0$

→ we can find V_{th}.



$V_{th} = \left(\frac{R_2}{R_1+R_2}\right)(10) - 5$ * نضرب و نقسم بـ $\frac{R_1}{R_1}$ *

$= \frac{R_1}{R_1}\left(\frac{R_2}{R_1+R_2}\right)(10) - 5$

R_{th}

$\therefore\ R_1 = 344\ k\Omega$.

$R_2 = 467\ k\Omega$.

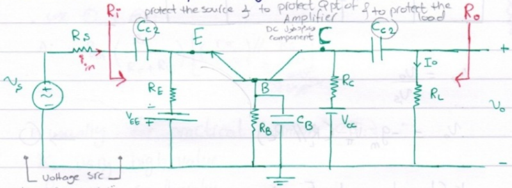
· Design حارج تجيب اسئلة *
Analysis - DC فقط اسئلة
\ AC

25-3/2014.

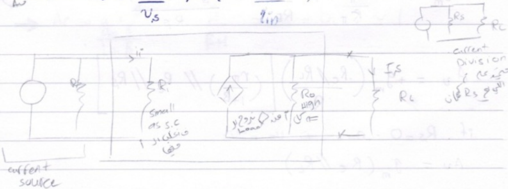
* Common Base Amplifier (CB) :-

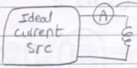
*** Features:-**

1. $A_v > 1$
2. $A_i \simeq 1$
3. small R_i
4. high R_o
5. CB - Amplifier ≡ Ideal current source. (without R_s)
6. used if the input signal is a current.



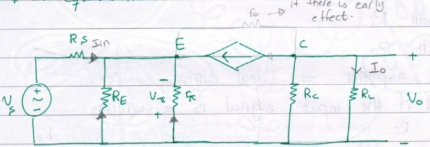
$$\text{Find}: A_v = \frac{v_o}{v_s}, \; A_i = \frac{i_o}{i_{in}}, \; R_o, \; R_i$$





the Reading of Ameter will still const !

* the equivalent :



$$A_v = \frac{v_o}{v_s}$$

$$v_o = -g_m V_\pi (R_L // R_C) \rightarrow (1)$$

. KCL at node E ⇒

$$g_m v_\pi + \frac{v_\pi}{r_\pi} + \frac{v_\pi}{R_E} + \frac{v_s - (-v_\pi)}{R_S} = 0 \rightarrow (2)$$

$$A_v = +g_m \left(\frac{R_C // R_L}{R_S}\right)\left[\left(\frac{r_\pi}{1+\beta}\right) // R_E // R_S\right]$$

if $R_S = 0\ \Omega \Rightarrow v_\pi = -V_s$

$$A_v = g_m (R_C // R_L)$$

KCL, KVL, Current division

25-3/2014. Tue.

$$A_i = \frac{I_o}{I_{in}}$$

$$I_o = -g_m V_\pi \frac{R_c}{R_c + R_L} \quad \text{(current division)} \rightarrow ①$$

KCL at Emitter:

$$I_{in} + g_m V_\pi + \frac{V_\pi}{R_E} + \frac{V_\pi}{r_\pi} = 0$$

$$V_\pi = -I_n \left[\left(\frac{r_\pi}{1+\beta} \right) // R_E \right] \rightarrow ②$$

. use ① & ②:

$$A_i = g_m \left(\frac{R_c}{R_c + R_L} \right) \left[\left(\frac{r_\pi}{1+\beta} \right) // R_E \right]$$

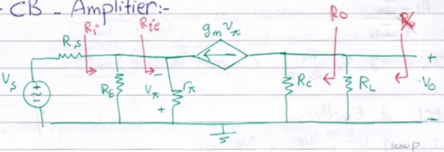
من توحيد المقامات بتظهر علطول.

* usually for practical common CB:-
R_E very high value.
R_L very small value.

$$\rightarrow A_i \simeq \frac{g_m r_\pi}{1+\beta} = \frac{\beta}{\beta+1} = \alpha = 0.99 \simeq 1$$

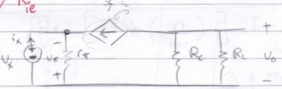
27 - 3/2014 Thu.

* CB - Amplifier:-



loop.
current Division
Voltage Division

$R_i = R_E // R_{ie}$



$R_{ie} = \dfrac{v_x}{i_x}$

* find R_o in this cct. *

[Ac-equivalent ... then gains ...

KCL at node E :-

$i_x + \dfrac{v_\pi}{r_\pi} + g_m v_\pi = 0$

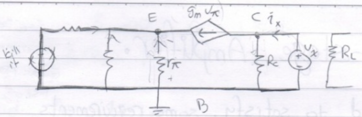
but $v_\pi = -v_x$

$\Rightarrow i_x - \dfrac{v_x}{r_\pi} - g_m v_x = 0$

$R_{ie} = \dfrac{v_x}{i_x} = \dfrac{r_\pi}{1 + r_\pi g_m} = \dfrac{r_\pi}{1+\beta} \rightarrow$ small value.

- $R_i = R_E // R_{ie}$ " small value "

27-3/2014. Thu.



KCL at C:-

$$i_x - \frac{v_x}{R_c} - g_m v_\pi = 0 \rightarrow (1)$$

KCL at E:-

$$g_m v_\pi + \frac{v_\pi}{r_\pi} + \frac{v_\pi}{R_E} + \frac{v_\pi}{R_S} = 0$$

$$\rightarrow v_\pi \left(g_m + \frac{1}{r_\pi} + \frac{1}{R_E} + \frac{1}{R_S} \right) = 0 \quad \therefore v_\pi = 0$$

$\therefore$ from (1): $R_o = \dfrac{v_x}{I_x} = R_c.$

* إلى هنا مادة الإمتحان *

27-3/2014

• Multi-stage Amplifier •

لتحقيق عدة requirement صعب التحقيق 1-stage.

it is used to satisfy some requirements that can not be satasfied by single stage.

Example : * CE without R_E → has a high A_v but unstable.

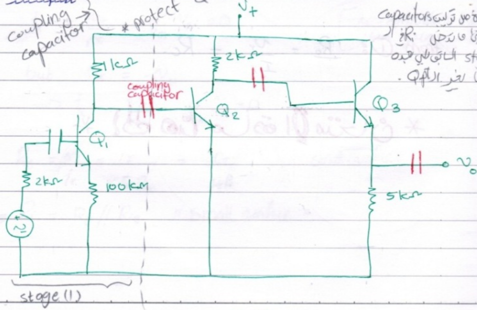
* CE with R_E → has low A_v but stable.

* CC has $A_v = 1$ but high R_i and R_o

Example { * protection src load

coupling capacitor → * protect Q-pt

الأهم ترتيب capacitors حتى ما ندخل R_i الـ stage التالي لي قبله وما تغير الـ Q-pt.

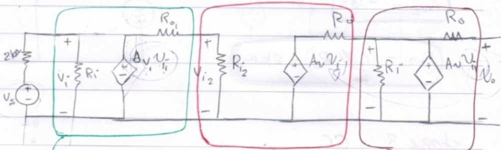


27-3/2014. Thu

For Q_1 : $\beta = 100$, $r_\pi = 1\ k\Omega$

For Q_2 & Q_3 : $\beta = 100$, $r_\pi = 0.5\ k\Omega$

Find $A_v = \dfrac{v_o}{v_s}$:



$v_1 = v_s \dfrac{R_i}{R_1 + R_s}$

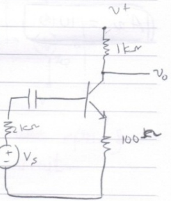
$v_i = A_{v_1} v_{in_1} \dfrac{R_{i2}}{R_{i2} + R_{o1}}$

R_o, A_v — مارح نستخدم هادي الطريقة ! بنحل كل stage لحاله وبنوجد

A_v & R_o لكل stage

*Solution :-

stage 1: $A_{v_1} = \dfrac{-\beta R_C}{r_\pi + (1+\beta) R_E} \left(\dfrac{R_i}{R_i + R_s} \right)$



$R_i = \left[r_\pi + (1+\beta) R_E \right] // \underbrace{R_1 // R_2}_{\infty}$

$\therefore R_i = r_\pi + (1+\beta) R_E$

Sub ⇒

$\boxed{A_{v_1} = -7.63}$

$\boxed{R_{o_1} = R_C = 1\ k\Omega}$

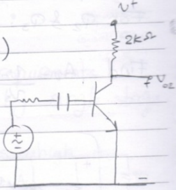
27-3/2014

stage 2:- CE without R_E.

$$A_{v2} = -g_m \left(\frac{\overbrace{R_1 // R_2}^{\infty} // r_\pi}{\underbrace{R_1 // R_2 // r_\pi + R_s}_{R_{o1}}} \right) (\cancel{r_o} // R_c)$$

$$\boxed{A_{v2} = -133}$$

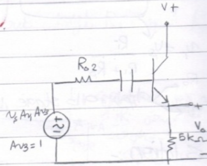
$$\boxed{R_{o2} = r_o // R_c = 2k\Omega}$$



stage 3:- CC

$$v_o = v_s \, A_{v1} \, A_{v2} \, A_{v3}$$

$$A_v = \frac{v_o}{v_s} = \underbrace{A_{v1}}_{-7.63} \, \underbrace{A_{v2}}_{133} \, \underbrace{A_{v3}}_{1}$$

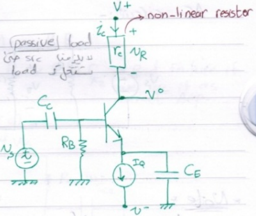


$$\boxed{A_v = 1010}$$

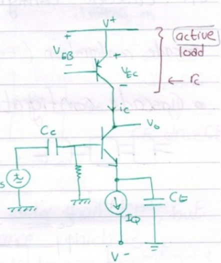
High gain عالي

* Active load:

advantage:-
high r_c, so
high A_v

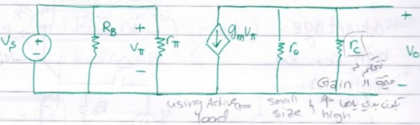


advantages:-
1. small size, so can be used in ICs.
2. r_c is high, so high A_v.
3. we dont need by pass capacitor.



This is an example of using the npn & pnp transistors in the same circuit.

AC- circuit :-



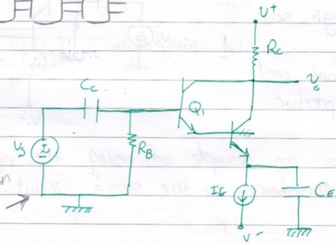
* Note *

Multistage Amplifier could be cascade configration OR cascode configration.

as parallel. — output of the first stage is input to the second stage (as series).

cascade configration (Ex: Darlington pair circuit)

• Cascade configration:-

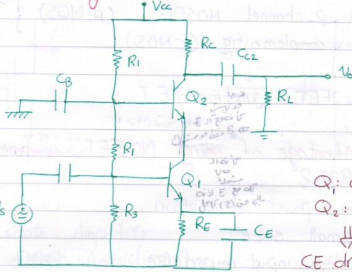


Darlington pair cct

Features:-

1. High current gain : $A_i \simeq \beta_1 \beta_2$
2. High input resistance: $R_i \simeq 2\beta_1 r_{\pi_2}$ → Bad Feature if we use it as current Amp.

• Cascode configration:-



Q_1: CE
Q_2: CB
⇓
CE drive CB

*Advantage:-

Range of freq. to the input signal, it be linear there
4 signal [illegible] user [illegible]

• CB stage has abandwidth <u>wider</u> than (good) CE, but CB has low (Bad) input impedance. which is a limitation in many application. CE → high input Z

But cascode configration has a wide Bandwidth and high input impedance!

من جهة ال input مضمونة ال CE ومن جهة ال output مضمونة CB

3-4-2014

* Field Effect Transistor (FET) Amplifier *

FET:- [illegible]

1. MOSFET: metal - oxide - semiconductor FET.
   - * n-channel MOSFET (nMOS)
   - * p-channel MOSFET (pMOS)
   - * complementry (CMOS)

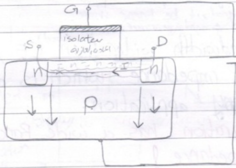
   } → Enhancement, → Depletion.

2. JFET: junction FET.

الا بتوبان تستخدم

- Advantage of using MOSFET compared with BJT?

1. low power dissipation.
2. Small size.
3. High input impedance. → because there is isolator



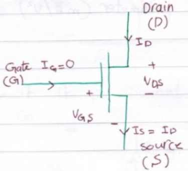
- holes will move with the Direction of Field ⟹ majority of n-channel
- $I_G = 0$, $I_S = I_D$

(ياخذ كل ال V) good ← loading effect

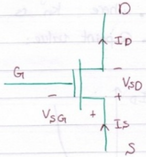
But: $g_{m(BJT)} \gg g_{m(FET)}$ Gain. نتحمل بالاصل في تكبير ال

So that $A_{v(BJT)} \gg A_{v(FET)}$ by using نستطيع حل المشكلة Multistage.

n-channel MOSFET



p-channel MOSFET



• we will have:-

1. common Gate Amplifier
2. Common Drain Amplifier
3. Common Source Amplifier

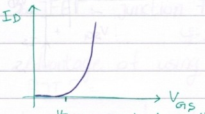
* The Transistor should be in Saturation Mode to work as Amplifier.

• DC-analysis :-

1. Draw DC-equivalent cct , $-||- : o.c$
   AC-src: S.C
2. use $I_{DQ} = K_n (V_{GSQ} - V_{TN})^2$
   Finding it from input loop ↑ then use eq'n

• where K_n is the conduction parameter (mA/V^2)

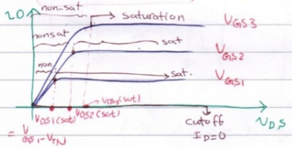
• Q-point value: I_D, $\underline{V_{GS}}$, V_{DS}
controller



V_T : Threshod voltage.

→ if $V_{DSQ} > V_{DS(sat)}$, then saturation Mode.
↳ Finding it from output loop.

$V_{DS(sat)} = V_{GSQ} - V_{TN}$



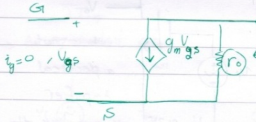
sat ↓ ⇐ ↑ V_{GS}

منطقة ال saturation
تعتمد على قيمة ال V_{DS}
مو مثل ال BJT
كل ما زادت V_{GS} بـ منطقة
ال sat تقل

* AC-analysis *

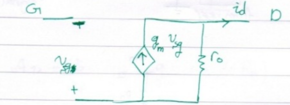
- Draw AC-equivalent cct:

• if it n-channel:-



if theres early effect.

• if it p-channel:-



→ $g_m = 2k_n(v_{GSQ} - V_{TN})$ → for n-channel

but $g_m = 2k_p(v_{SGQ} + V_{TP})$ to p-channel

→ $r_o = \dfrac{1}{\lambda I_{DQ}}$ • where λ is the channel length modulation parameter. (+ve value)

→ $i_d = g_m v_{gs} = 2k_n(v_{GSQ} - V_{TN})\, v_{gs}$, if $r_o = \infty$

* Example:-

Given :

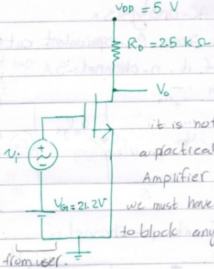
$V_{TN} = 1V$

$k_n = 0.8\, mA/V^2$

$\lambda = 0.02\ V^{-1}$

find $A_v = \frac{v_o}{v_i}$

• it is common source.



it is not a practical Amplifier

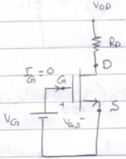
we must have -||- to block any DC signal

DC-analysis:-

• $V_{GSQ} = V_G = 2.12\,V$

• $I_{DQ} = \underset{0.8}{k_n}\left(\underset{2.12}{V_{GSQ}} - \underset{1}{V_{TN}}\right)^2$

$I_{DQ} = 1\,mA$



• $V_{DSQ} = \underset{5}{V_{DD}} - I_D \underset{2.5}{R_D} = 2.5\,V$

$V_{DSQ} \overset{?}{>} (V_{DS(sat)}) = V_{GS} - V_{TN}$ ✓ (saturation)

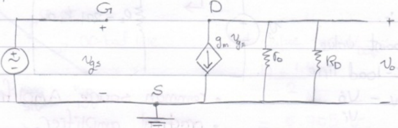
so we can ~~do~~ use the transistor as amplifier

6-4/2014

AC- analysis:-

- $g_m = 2k_n(V_{GSQ} - V_{TN}) = 1.79 \ mA/V$
- $r_o = \dfrac{1}{\lambda I_{DQ}} = 50 \ K\Omega$ (early effect)

→ Ac-equivalent cct:-



$$A_v = \frac{v_o}{v_i} = -g_m (r_o // R_D)$$

$A_v = -4.26$ (BJT مع بالمقارنة ← small value)

- use the same circuit in the previous نفس المقدار Gain example, but with p-channel MOSFET

$\begin{cases} V_{DD} = -5 \ v \\ \text{and} \ \perp (2.12) \ \text{OR} \ \top (-2.12) \end{cases}$

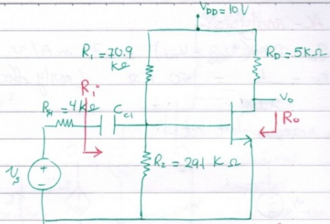
$A_v = -g_m (r_o // R_D)$ & it is the same value.

* Example :-

$V_{TN} = 1.5\ V$

$k_n = 0.5\ mA/V^2$

$\lambda = 0.01\ V^{-1}$



Find :-

1. Q-point value
2. DC-load line
3. $A_V = \frac{V_o}{V_i}$
4. R_i
5. R_o

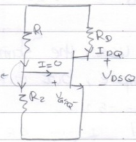
- common source Amplifier.
- practical amplifier.

ولو كان في ـــ عندك ⇐ معادلتين (واحدة تربيعية)

DC-analysis:-

voltage Division

$V_{GSQ} = 10 \times \frac{R_2}{R_2 + R_1} = 2.91\ V$



$I_{DQ} = k_n \left(V_{GSQ} - V_{TN} \right)^2 = 1\ mA$

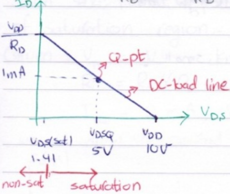
$V_{DSQ} = 10 - I_D R_D = 5\ V$

$V_{DSQ} \overset{?}{>} \left(V_{DS(sat)} = V_{GSQ} - V_{TN} \right)$ ✓ (saturation)

DC-load line:- $I_D \propto V_{DS}$

$$-V_{DD} + I_D R_D + V_{DS} = 0$$

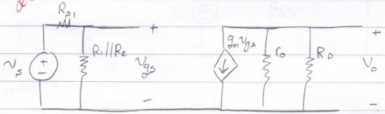
$$I_D = \frac{V_{DD}}{R_D} - \frac{V_{DS}}{R_D} \qquad \text{slope: } -\frac{1}{R_D}$$



• Best value for V_{DSQ}:

$$\frac{10 + 1.41}{2} = 5.705\ V$$

* AC-analysis:-



$$A_v = \frac{v_o}{v_i}$$

$$v_o = -g_m v_{gs} (r_o // R_o)$$

$$v_{gs} = v_s \frac{R_1 // R_2}{R_1 // R_2 + R_{S1}}$$

6-4/2014

$$A_v = -g_m \,(r_o \,//\, R_D)\left(\frac{R_1 // R_2}{R_1//R_2 + R_{S1}}\right) = -0.562.$$

$R_i = R_1 // R_2 = 20.6\,k\Omega$ (High value)

$R_o = r_o // R_D = 4.76\,k\Omega$ small!

8-4/2014

Design Example:-

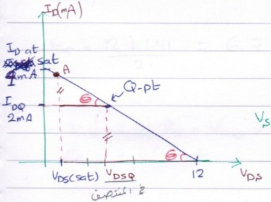
Design the bias of MOSFET (common source) such that the Q-point is in the middle of saturation region:-

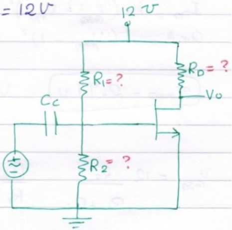
Given : $V_{TN} = 1V$, $k_n = 1\ mA/V^2$, $\lambda = 0.015\ V^{-1}$

$R_i = R_1 // R_2 = 100\ k\Omega$

$I_{DQ} = 2\ mA$, $V_{DD} = 12V$

we will draw the DC-load line:





the same tan of θ.

- at point A: $I_D = 4\ mA$

$I_{DA} = k_n (V_{GSA} - V_{TN})^2$

$\rightarrow V_{GSA} = 3V$

$\Rightarrow V_{DS(sat)} = V_{GSA} - V_{TN} = 2V$

[the same of at pt A]

8-4/2014 Tue

$V_{DSQ} = \frac{12+2}{2} = 7\ V$ Best value.

$-12 + I_{DQ} R_D + V_{DSQ} = 0$

$\boxed{R_D = 2.5\ k\Omega}$

$I_{DQ} = k_n (V_{GSQ} - V_{TN})^2$

$2mA = 1 (V_{GSQ} - 1)^2$

$\boxed{V_{GSQ} = 2.41\ V}$

$V_{GSQ} = 12 \frac{R_2}{R_1 + R_2} \quad \frac{R_1}{R_1}$

$V_{GSQ} = 12 \frac{R_1 R_2}{R_1 + R_2} \cdot \frac{1}{R_1}$

$2.41 = 12 (\underbrace{R_1 // R_2}_{100}) \frac{1}{R_1}$

$\therefore \boxed{R_1 = 498\ k\Omega}$ $\boxed{R_2 = 125\ k\Omega}$

- another Solution:-

$$V_{GSQ} = 12 \frac{R_i}{R_1} = \frac{1200}{R_1}$$

$$I_{DQ} = kn(V_{GSQ} - V_{TN})^2$$
$$2 = 1\left(\frac{1200}{R_1} - 1\right)^2$$

$$\sqrt{2} + 1 = \frac{1200}{R_1} \rightarrow R_1 = \frac{1200}{\sqrt{2}+1}$$

$$V_{DS(sat)} = 1.41 \text{ V}$$

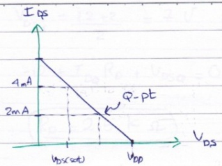
$$V_{DQ} = \frac{12 + 1.41}{2} = 6.7 \text{ V}$$

$$-12 + I_{DQ} R_D + V_{DSQ} = 0$$
$$R_D = 2.65 \text{ k}\Omega$$

ت-١١ ع-ح٢

practical & simulation
PCB OR
Bread board
multi-sim

10-4/2014 Thu.



$I_{D(sat)} = k_n(V_{GS(sat)} - V_{TN})^2$

$V_{GS(sat)} = 3V$

$V_{DS(sat)} = V_{GS(sat)} - V_{TN} = 2V$

$V_{DSQ} = \frac{V_{DD} + V_{DS(sat)}}{2} = 7$

from the output loop:

$\underset{12}{-V_{DD}} + \underset{2mA}{I_{DQ}} R_D + \underset{7}{V_{DSQ}} = 0$

$\rightarrow R_D = 2.5\ k\Omega$

$I_{DQ} = k_n(V_{GSQ} - V_{TN})^2$

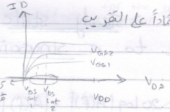
$V_{GSQ} = 2.41\ V$

$$V_{GSQ} = V_{DD} * \frac{R_2 \; R_1}{\underbrace{R_1+R_2}_{R_i}} \cdot \frac{1}{R_1}$$

$\rightarrow R_1 = 498 \text{ k}\Omega$

$R_2 = 125 \text{ k}\Omega$

اعتماداً على التقريب



كأنو كل النقاط قريبة من بعضها

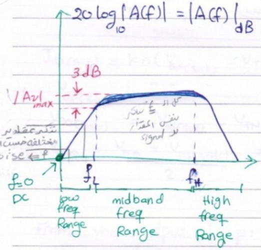
10-4/2014 Thu.

New Chapter

Frequency Response

Gain as a f'n of f

- it is steady state output of a linear sys. due to a sinusoidal input.



$f=0$: DC

$f>0$: AC

f_L: low corner - frequency

low 3dB frequency

break - point frequency

- Band width (BW) = $f_H - f_L$

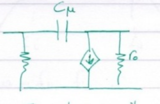
Gain indep. on freq

if it wide ⇒ Good Amplifier.

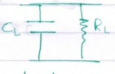
10-4/2014

بين ال user و Amp
او بين ال Amp & load

- Types of capacitors:-
  1. coupling and bypass capacitors ($\parallel R_C$ / $\parallel R_E$) → the same behavior for the both:- (Group 1)
  2. Transistor and load capacitors (Group 2)



Transistor capacitor



Load capacitor

capaciter <
- o.c
- s.c
- have impedance -

- In DC ($f = 0$) → all capacitors are open cct.

$$Z_c = \frac{1}{j2\pi f C} = \infty \ \Omega \qquad (f \to 0)$$

Amp. ال...

- In Low frequency range:

Group(1) : $Z_c = \dfrac{1}{j2\pi f C}$ ↑ كبيرة و ال ↓f ⇐ as balanced

Group(2) : open cct $\qquad Z_c = \dfrac{1}{j2\pi f C}$ (f ↓, C ↓ → 0) ⇒ Z_c: high value ∞ ∴ o.c

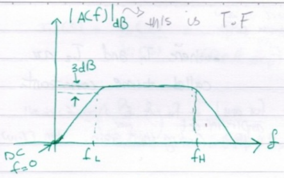
- In midband Range:

Group(1) : S. C

Group (2): open. cct

Group(1): High value
Group(2): Low "
بالمقارنة مع بعض

. High frequency range:
Group (1): short cct
Group (2): $Z_c = \frac{1}{j 2\pi f C}$



$BW = f_H - f_L$

Note: the values of capacitors in graph 1 >> values of capacitors in graph 2.

• Transfer Function: A(f)

→ S-Domain:

S ↓ From Laplace.

$S = j\omega = j\,2\pi f$ (complex frequency)

$Z_c = \frac{1}{j\omega C} = \frac{1}{SC}$

In general, $\underbrace{T(S)}_{\text{Transfer function}} = \frac{k\,(S-Z_1)\,(S-Z_2)\,\cdots\,(S-Z_n)}{(S-P_1)(S-P_2)\,\cdots\,(S-P_m)}$

$Z_1, Z_2 \dots Z_n$: Zeros of Transfer function

$P_1, P_2 \dots P_m$: poles of Transfer function.

K: constant.

→ To draw A(f) of amplifier, we will consider only two forms of T(S).

① $T_1(s) = k_1 \dfrac{1}{1 + s\tau_1}$ بعوض ال corner اللي عا اليمين

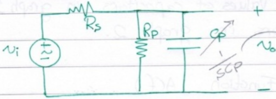
• where τ_1 and τ_2 are called time constant.

② $T_2(s) = k_2 \dfrac{s\tau_2}{1 + s\tau_2}$

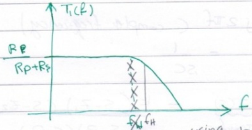
~~right~~ corner. يعوض left.

الهدف: تحديد ال f_H & f_L for any amplifier cct then finding the max Gain. then Draw it.

• $T_1(s)$: This is transfer function of the following cct:



then fing $V_o = V_i(s) * \dfrac{R_P // \frac{1}{sC_P}}{(R_P // \frac{1}{sC_P}) + R_s}$



using bood Plot to Find f_H

$T_1(s) = \dfrac{V_o(s)}{V_i(s)}$

$V_o(s) = V_i(s) * \dfrac{R_P // \frac{1}{sC_P}}{(R_P // \frac{1}{sC_P}) + R_s}$

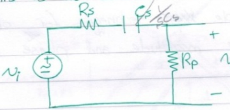
13-4/2014

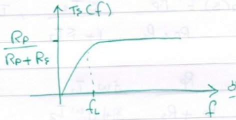
$$T_1(S) = \frac{V_o(S)}{V_i(S)} = \frac{R_P // \frac{1}{SC_P}}{(R_P // \frac{1}{SC_P}) + R_S}$$

$$= \left(\frac{R_P}{R_P + R_S}\right) \frac{1}{1 + S(R_P // R_S) C_P}$$

$$\rightarrow k_1 = \frac{R_P}{R_P + R_S} \quad \& \quad \tau_1 = (R_P // R_S) C_P$$

- $T_2(S)$: This is the transfer function of this cct.





High Pass filter

يسمح بمرور الـ f العالية

$$T_2(S) = \frac{v_o(S)}{v_i(S)}$$

$$v_o(S) = v_i(S) * \frac{R_P}{R_P + R_S + \frac{1}{SC_S}}$$

$$T_2(s) = \frac{S C_s R_P}{1 + (R_p + R_s) C_s}$$

$$T_2(s) = \left(\frac{R_P}{R_P + R_s}\right) \cdot \frac{S (R_s + R_P) C_s}{1 + (R_s + R_c) C_s S}$$

where $k = \frac{R_P}{R_P + R_s}$ & $\tau = (R_s + R_P) C_s$

* Bode Plot :-

it is a simple ~~[illegible]~~ technegue for obtaing approximate plots of the magnitude and phase of transfer function.

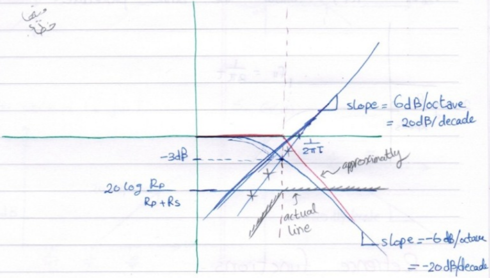
To Plot $T_2(s) = \frac{R_P}{R_P + R_s} \frac{s\tau_2}{1 + s\tau_2}$, $\tau_2 = (R_s + R_P) C_s$

$$\rightarrow T_2(\omega) = \frac{R_P}{R_P + R_s} \frac{j\omega \tau_2}{1 + j\omega \tau_2}$$

$$|T_2(\omega)| = \frac{R_P}{R_P + R_s} \frac{\omega \tau_2}{\sqrt{1 + (\omega \tau_2)^2}}$$

$$|T_2(f)| = \frac{R_P}{R_P + R_S} \cdot \frac{2\pi f \tau_2}{\sqrt{1+(2\pi f \tau_2)^2}}$$

$$|T_2(f)|_{dB} = 20 \log \frac{R_P}{R_P+R_S} + 20 \log 2\pi f \tau_2 - 20 \log \sqrt{1+(2\pi f \tau_2)^2}$$



. Octave:-

$20 \log 2 = 6\ dB$

$20 \log 4 \ (\times 2) = 12\ dB \ (+6dB)$

$20 \log 8 \ (\times 2) = 18\ dB \ (+6\ dB)$

$20 \log 16 \ (\times 2) = 24\ dB \ (+6\ dB)$

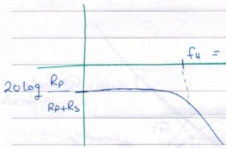
· decade:

$20 \log 10 = 20\,dB$

$20 \log 100 = 40\,dB$ ($\times 10$, $+20$)

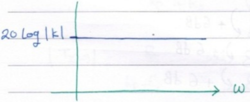
$20 \log 1000 = 60\,dB$ ($\times 10$, $+20$)

· For $T_1(f)$ follow the same procedure.

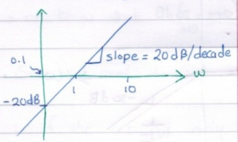


· Refrence functions:-

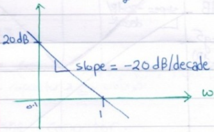
1. $T(\omega) = k$



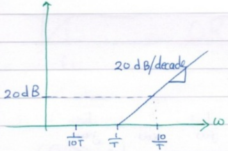
2. $T(\omega) = j\omega$



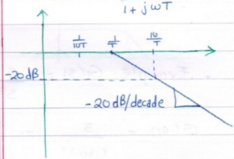
3. $T(\omega) = \frac{1}{j\omega}$



4. $G(\omega) = 1 + j\omega T$



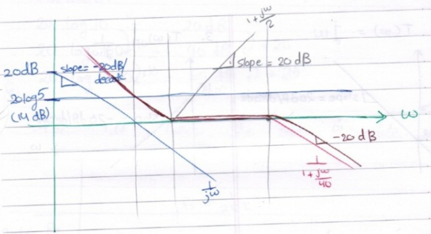
5. $G(\omega) = \frac{1}{1 + j\omega T}$



- Example:- Plot the following : $G(s) = \frac{100(s+2)}{s(s+40)}$

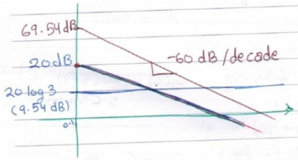
$$G(j\omega) = \frac{100(j\omega + 2)}{j\omega(j\omega + 40)}$$

$$G(j\omega) = \frac{100 \times 2\left(1 + \frac{j\omega}{2}\right)}{j\omega \times 40\left(1 + \frac{j\omega}{40}\right)} = \frac{5\left(1 + \frac{j\omega}{2}\right)}{\left(1 + \frac{j\omega}{40}\right)}$$



• Example: $G(s) = \frac{3}{s^3}$

$$G(\omega) = \frac{3}{(j\omega)^3} = 3 \cdot \frac{1}{j\omega} \cdot \frac{1}{j\omega} \cdot \frac{1}{j\omega}$$



17-4/2014 Tue

• Short circuit and Open circuit time const.

→ we know that $f_{3dB} = \frac{1}{2\pi\tau}$

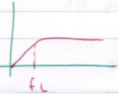
• So, we need to find τ (Time constant), How?!

شو ماكان نوع ال capacitor .

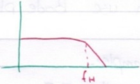
1. if the cct has only one capacitor:

$\tau = R_{eq} C$

↳ seen by C.

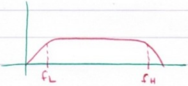


OR



2. if the cct has two capacitors:-

$(C_1 \gg C_2)$



$\tau_L = R_{eq} C_1$, $Z_c = \frac{1}{j 2\pi f C} \simeq \infty$

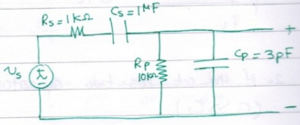
where C_2 will be open cct

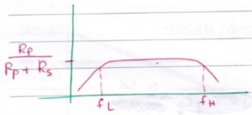
$\Rightarrow f_L = \dfrac{1}{2\pi \tau_L}$

$\tau_H = R_{eq}\, C_2$, $Z_c = \dfrac{1}{j 2\pi f c} \simeq 0$, $f \rightarrow \infty$

3. if the cct has more than two capacitor:
or ($C_1 = C_2$)
→ we need to find the transfer function $\dfrac{V_o(s)}{V_s(s)}$
then use Bode plot to draw this cct.

- Example:-
Draw the T.F $\dfrac{V_o(f)}{V_s(f)}$ and Find the Band width of the Given cct:





17-4/2014

- $f_L = \frac{1}{2\pi \tau_L}$, $\tau_L = R_{eq} C_s$ (C_p : O.C)

$\tau_L = (R_s + R_p) C_s = 1.1 \times 10^{-2}$ sec

$f_L = 14.5$ Hz

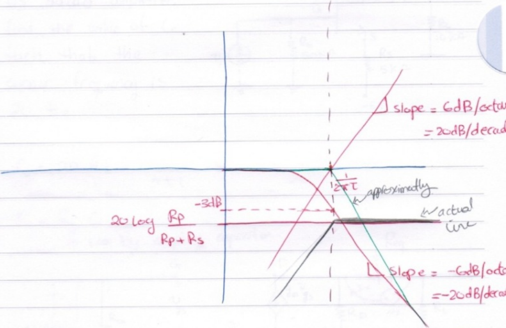
- $f_H = \frac{1}{2\pi \tau_H}$, $\tau_H = R_{eq} C_p$ (C_s: S.C)

$\tau_H = (R_s // R_p) C_p = 2.73 \times 10^{-9}$ sec

$f_H = 58.3$ M Hz

- $BW = f_H - f_L = 58.3$ M Hz

ناقص محاضره .

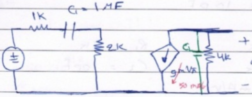


slope = 6dB/octave
= 20dB/decade
$\frac{1}{2\pi\tau}$
approximatly
-3dB
$20 \log \frac{R_p}{R_p+R_s}$
actual line
slope = -6dB/octave
= -20dB/decade

No.

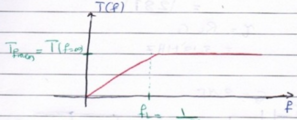
Lecture 20-4-2014

Ex:



Sketch the bode plot of the transfer function magnitude

Diagram of transfer function.



$\Rightarrow T_{max}(f) = T(f=\infty) = \frac{v_o}{v_i}$

C_1 is short circuit

$v_o = -g_m v_\pi * 4$

$v_\pi = v_i \frac{2}{2+1}$

$\Rightarrow \frac{v_o}{v_i} = -g_m * R_L * \frac{2}{2+1} = -133$

$|T_{max}(f)| = 133$

$\Rightarrow f_L = \frac{1}{2\pi\tau} = 53.1 \text{ Hz}$

$\tau = R_{eq} * C = (1+2) * 1\mu = 3 \text{ m sec}$

Ex:- Same example. without C_1, assume C_L parallel with R_L = 10 pF

R_S = 0.5 K $\quad$ R_L = 5 k

V_π = 1.5 k $\quad$ C_L = 10 pF

g_m = 75 mA/v.

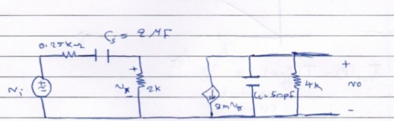
$$|T_{max}(f)| = |T(f_{o})| = g_m * R_L * \frac{1.5}{1.5+0.5}$$

$$= \boxed{281}$$

$$f_H = \frac{1}{2\pi \tau} \qquad \tau = R_L C_L$$

$$= 3.18 \text{ MHZ}$$

Ex: 3



Sketch the Bode plot of the transfer function magnitude

⇒ $C_s \gg C_L$

at low freq ⇒ $Z_c = \frac{1}{2\pi f C_L}$ $\quad$ C_L: open circuit

C_s: has an effect

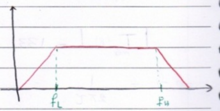
$$f_L = \frac{1}{2\pi \tau_L}$$

$\tau_L = R_{eq} C_s$ (C_L open ckT)

$= 2.25 \times 10^3 * 2 \times 10^{-6}$

$= 4.5$ m sec

∴ f_L = 35.4 HZ



No.

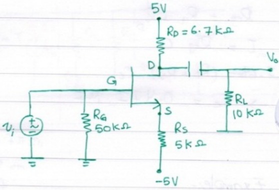
$$f_H = \frac{1}{2\pi \tau_H}$$

$\tau_H = R_{eq} \, C_L$ (C_S : short ckt)

$$\tau_H = 4\times10^{3} * 50\times10^{-12}$$
$$= 0.2 \ \mu sec$$

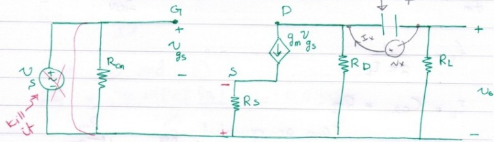
$$f_H = 0.796 \ MHz$$

Example:-
This circuit is used as audio amplifier, find the value of C_c such that the corner frequency is 20 Hz.



$f_L = 20\,Hz = \frac{1}{2\pi\tau} \rightarrow \tau = 7.96$ msec

$\tau = R_{eq}\, C_c$
↳ seen by coupling capacitor.



$v_{gs} = -R_S * g_m v_{gs}$

$v_{gs}(1 + R_S g_m) = 0$

$\boxed{v_{gs} = 0}$

22-4/2014

$R_{eq} = R_L + R_D$

$\tau = R_{eq} \, C_c$

$7.69m = (R_D + R_L) \, C_c$

$\rightarrow C_c = 0.477 \; \mu F$

قيمة ال Capacitor تؤثر
قيمة ال corner

$\frac{1}{j 2\pi f C\uparrow} = 0$

as S.C

Example:-

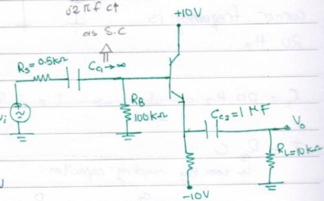
$B = 100$

$V_A = 120 \; V$

$C_{c2} = 1 \; \mu F$

$r_\pi = 3.10 \; k\Omega$

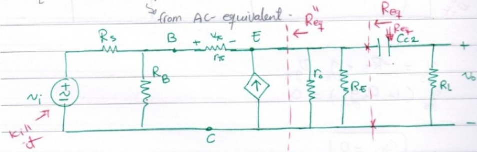
$g_m = 32.2 \; mA/V$



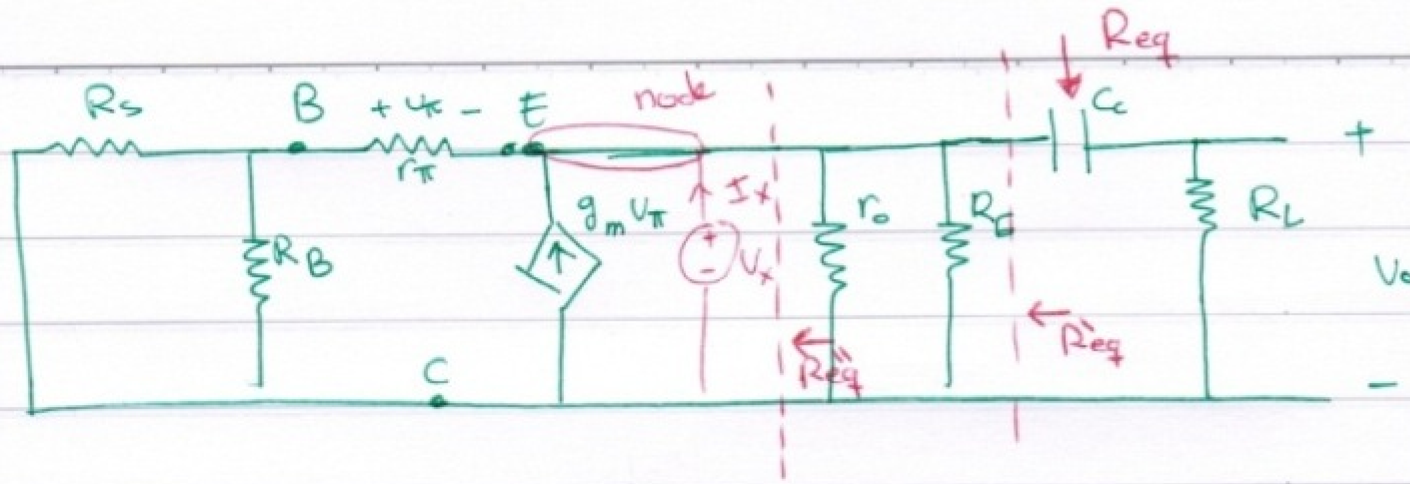
$f_L = \frac{1}{2\pi \, \tau_L}$

$\tau_L = C_{c2} * R_{eq}$

from AC equivalent.



22-4/2014



$$R_{eq} = R_L + R'_{eq}$$

KCL at node E:

$$I_x + g_m v_\pi = \frac{-v_\pi}{r_\pi} \rightarrow (1)$$

$$v_\pi = -v_x \frac{r_\pi}{r_\pi + (R_B // R_s)} \rightarrow (2)$$

$$R''_{eq} = \frac{v_x}{I_x}$$

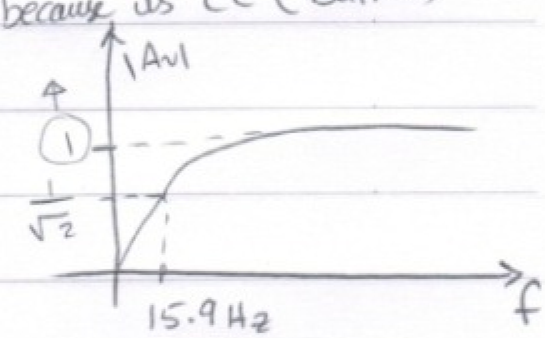
from (2) and (1) →

$$R''_{eq} = \frac{r_\pi + (R_s // R_B)}{1 + \beta} = 0.0356$$

$$\rightarrow R'_{eq} = 35.5 \ \Omega$$

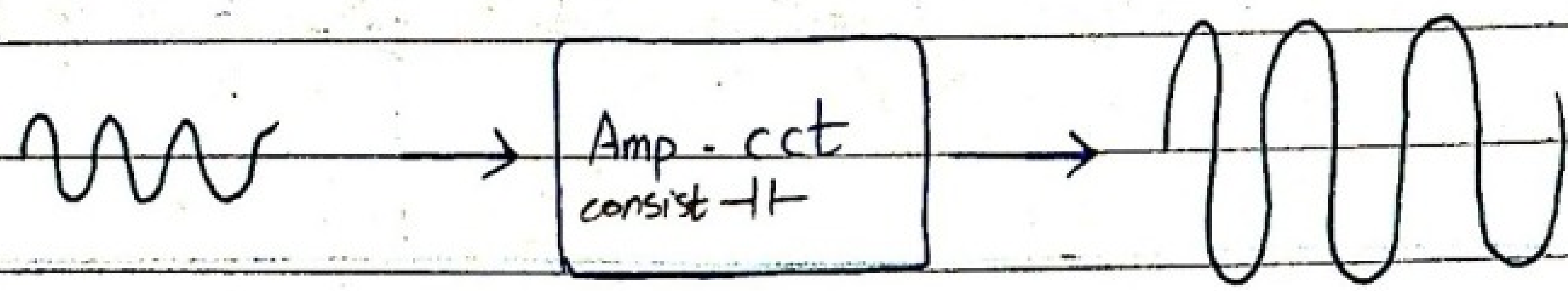
$$f_L = \frac{1}{2\pi \tau_L} = 15.9 \text{ Hz}$$

because its CC (Buffer)

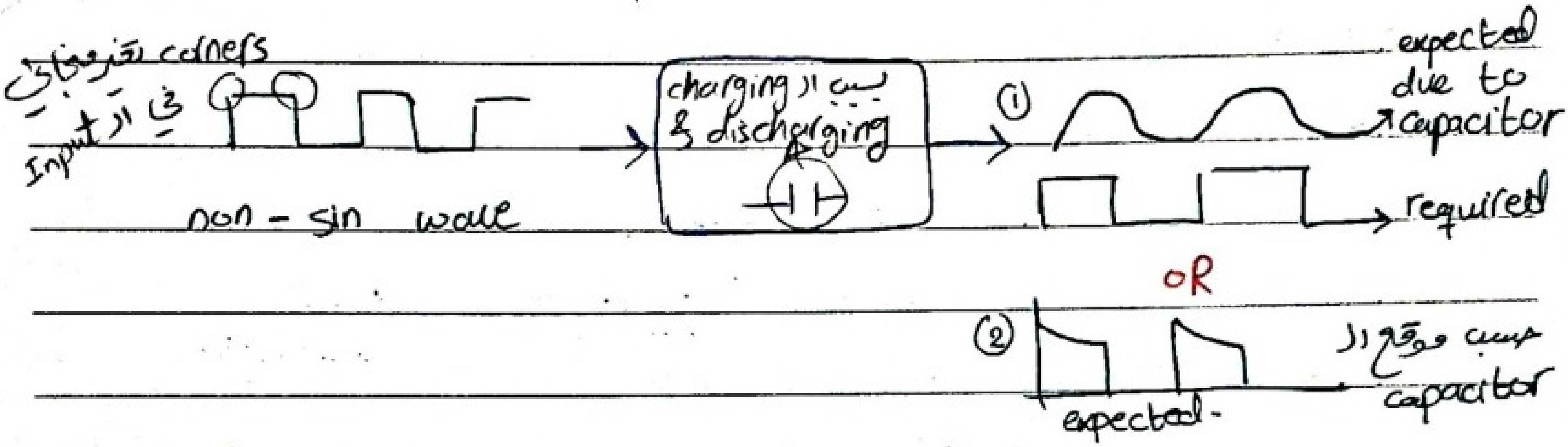


24-4/2014

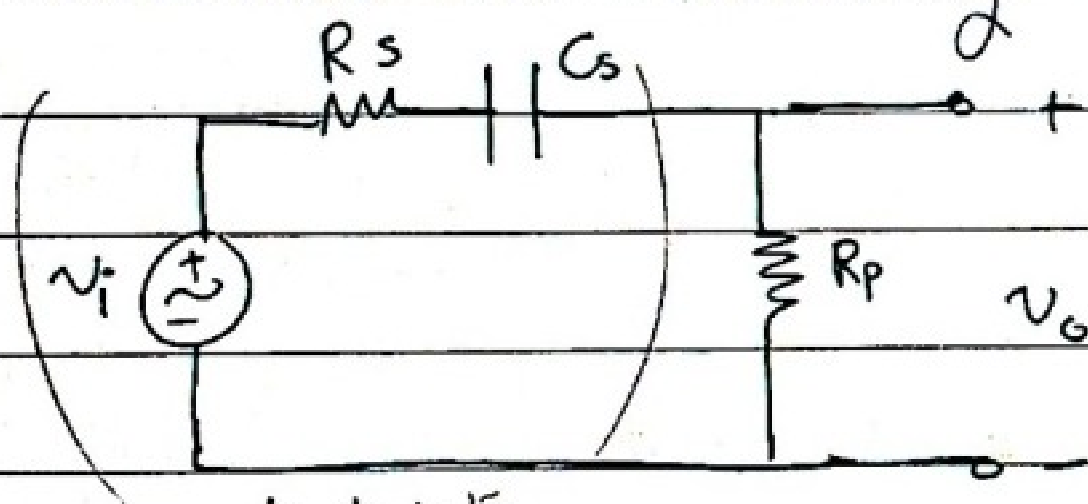
Time Response:-



Sin wave — sin wave



• Consider the following cct :-



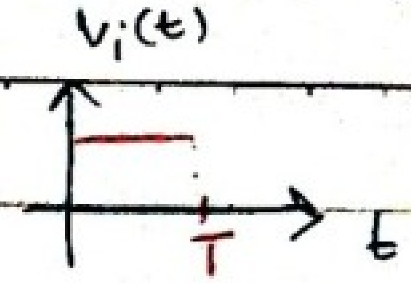
تمثل ال input cct for Amp.

$$\frac{v_o(s)}{v_i(s)} = \frac{R_P}{R_P + R_S} = \frac{S(R_S + R_P)C_S}{1 + S(R_S + R_P)C_S}$$

$$T(s) = \frac{v_o(s)}{v_i(s)} = k_2 \frac{S\tau_2}{1 + S\tau_2}$$

24/4/2014 Thu.

if $V_i(t) = u(t)$: unit step function.



what is $V_o(t)$?!

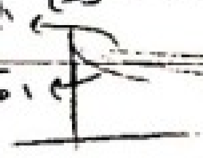
$V_o(s) = V_i(s)\, T(s)$

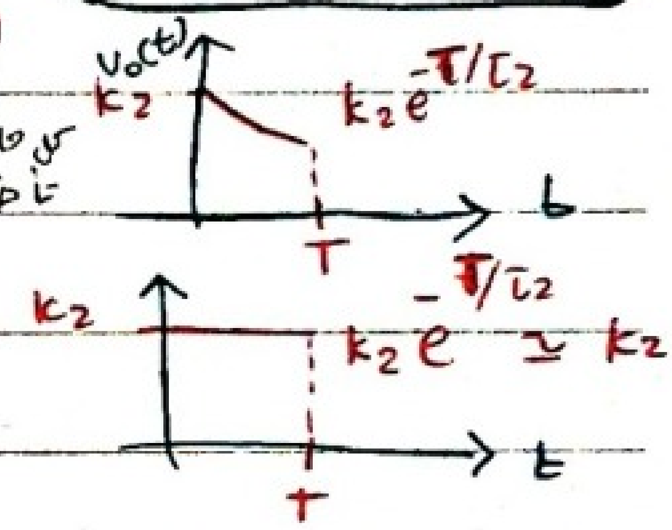
$V_o(s) = \frac{1}{\cancel{s}} \cdot k_2 \frac{\cancel{s}\tau_2}{1 + s\tau_2}$

by Laplace Transform

$V_o(s) = k_2 \frac{\tau_2}{1 + s\tau_2}$ $\xrightarrow[\text{laplace Transform}]{\text{inverse}}$ $\boxed{V_o(t) = k_2 e^{-t/\tau_2}}$

كل ما زاد τ_2 ⟸ عملية التفريغ تأخذ زمناً طويلاً





But the required $V_o(t)$: and to get it ⟹

$k_2 \simeq k_2 e^{-T/\tau_2}$

$\rightarrow e^{-T/\tau_2} \simeq 1$

$\frac{T}{\tau_2}$ very small value.

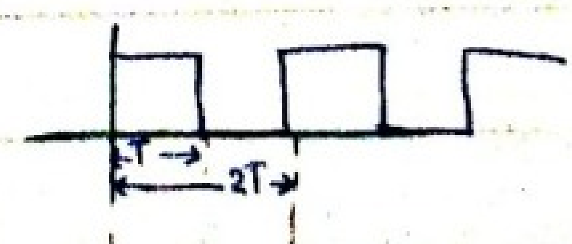
⟹ $\tau_2 \gg T$

$C_s(R_s + R_p) \gg T$

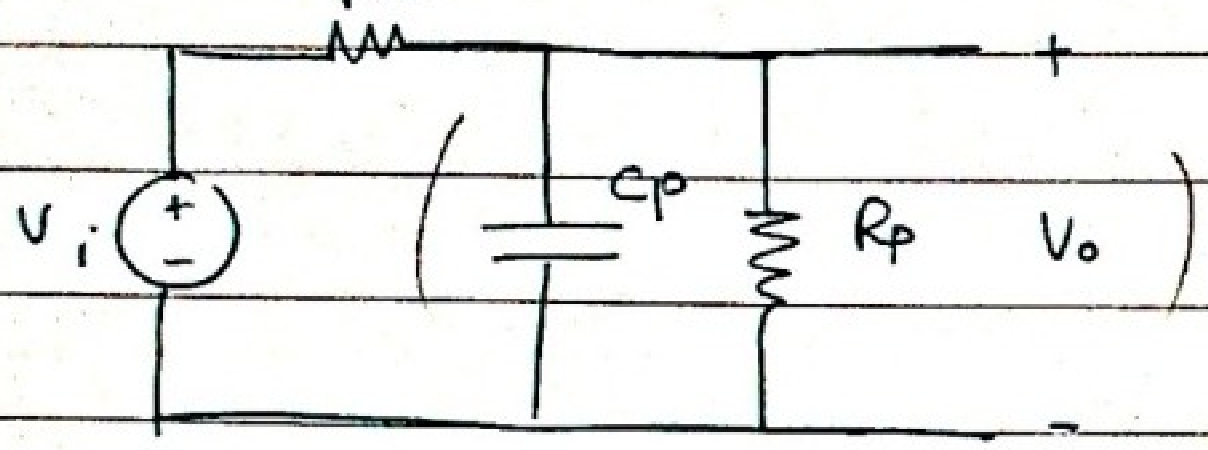
↳ should be very large.

min value to get C_s → $\tau_2 = 10T$

$\boxed{\tau_2 \geqslant 10\,T}$ → $f_{vi} = \frac{1}{2T}$



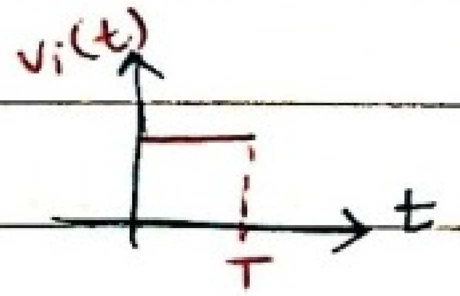
- consider the following cct:-



as output cct in Amplifier.

$$\frac{V_o(s)}{V_i(s)} = \frac{R_p}{R_p + R_s} \cdot \frac{1}{1 + s(R_s // R_p) C_p}$$

$$= k_1 \frac{1}{1 + s\tau_1}$$



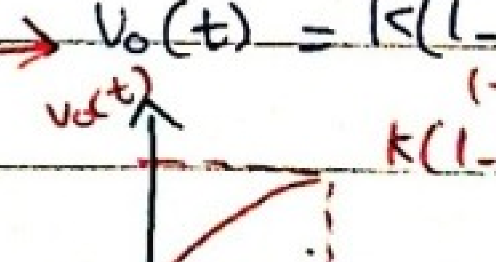
→ if the input $v_i(t) = u(t)$

what is the output ?!

$$V_o(s) = V_i(s) \cdot T(s)$$

$$= \frac{1}{s} \cdot \frac{k_1}{1 + s\tau_1}$$

$$V_o(s) = \frac{k_1}{s} \cdot \frac{1}{1 + s\tau_1} \xrightarrow[\text{Transform}]{\text{inverse laplace}} V_o(t) = k(1 - e^{-t/\tau_1})$$

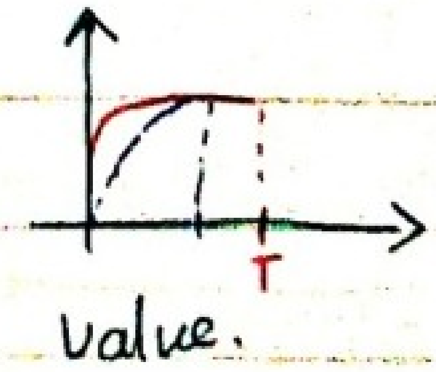


- To get the required $V_o(t)$:

$\tau_1 \ll T$

$C_p (R_p // R_s) \ll T$

↳ we need C_p to be very small value.

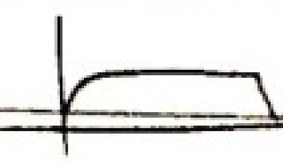


24/4/2014 Thu.

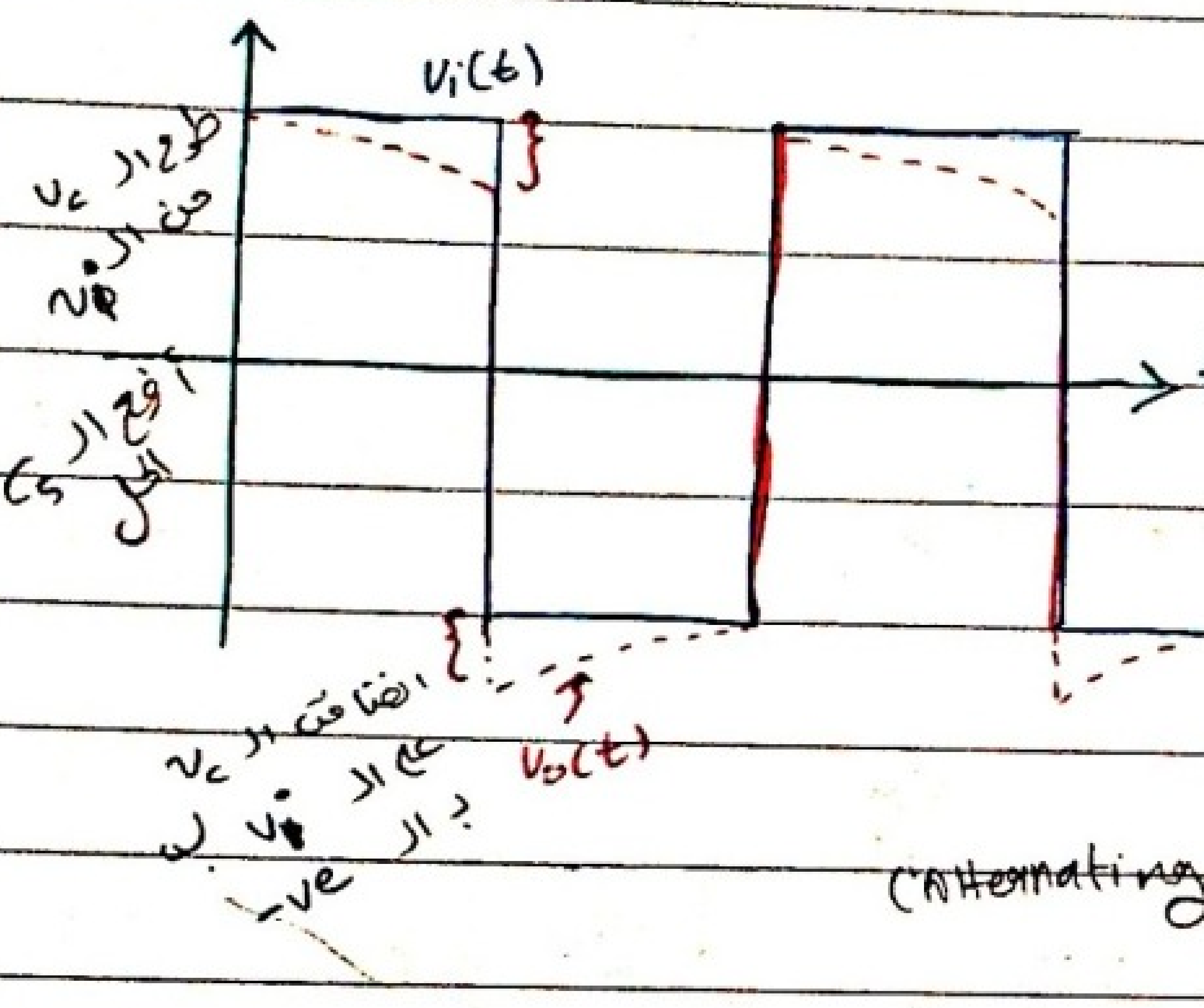
Time Response & frequency Response.

$\boxed{\tau \gg \frac{T}{10}}$

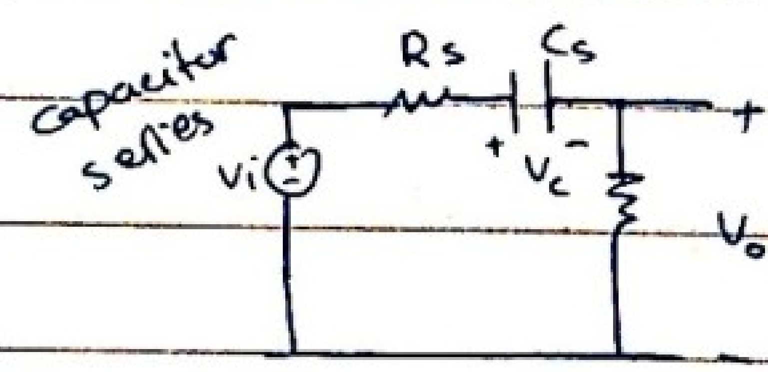
• تعني كل شي عن ال Time Response



° وكفيتها انو ال T.F مبين شكله.



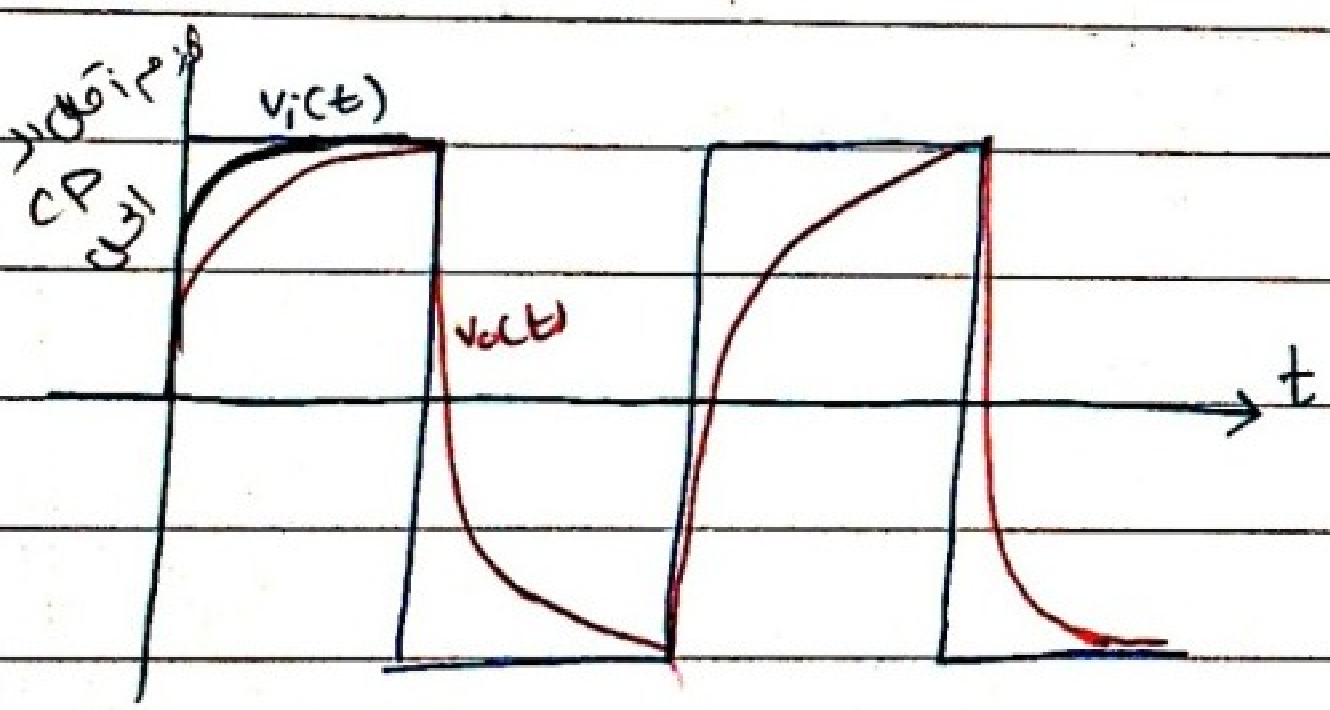
→ for the first cct:



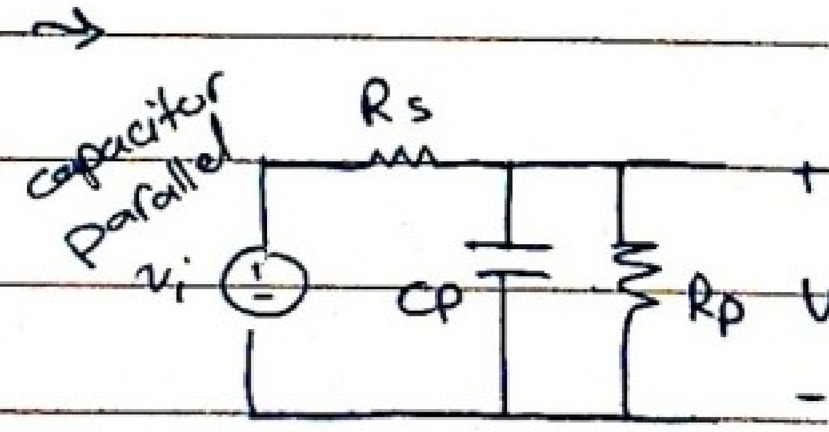
$$-v_i + V_c + V_o = 0$$

$$v_o = V_i - V_c$$

و حين تنعكس ال v_i / عكس ال signal (Alternating)



→



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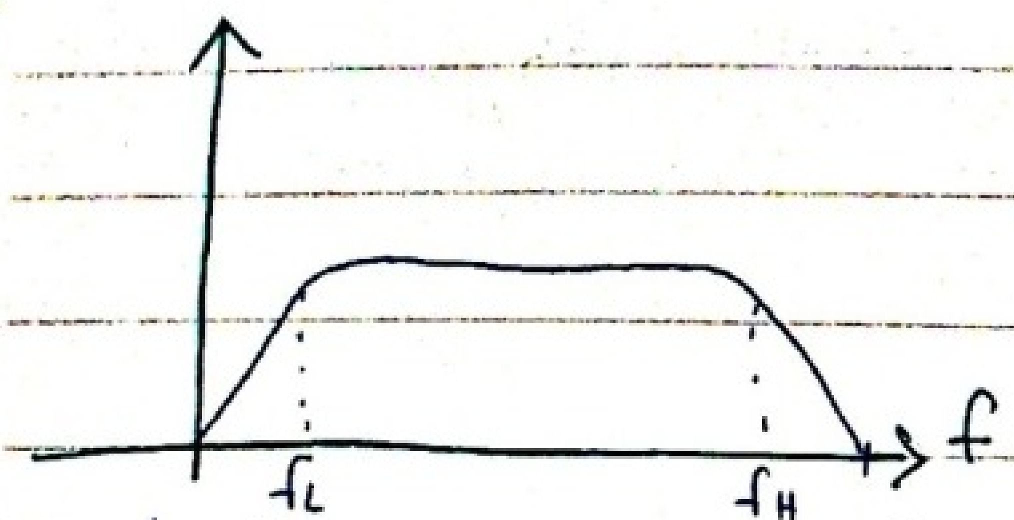
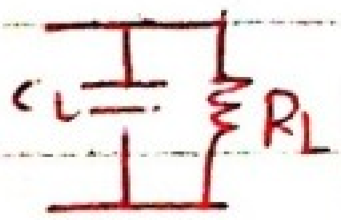
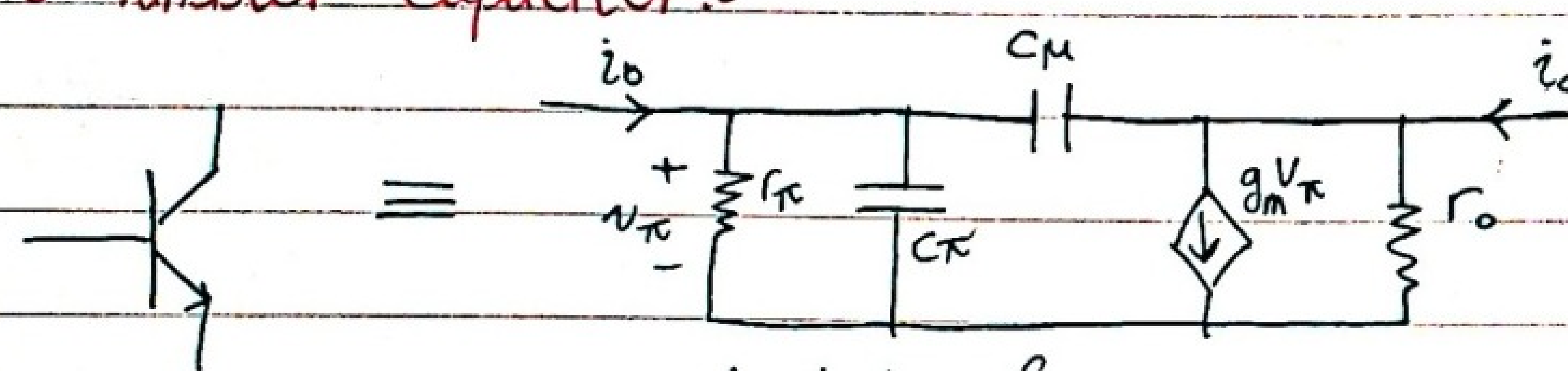


due to coupling and bypass capacitor

due to transistor and load capacitor → parallel to R_L



- Transistor capacitor:-



at high frequency.

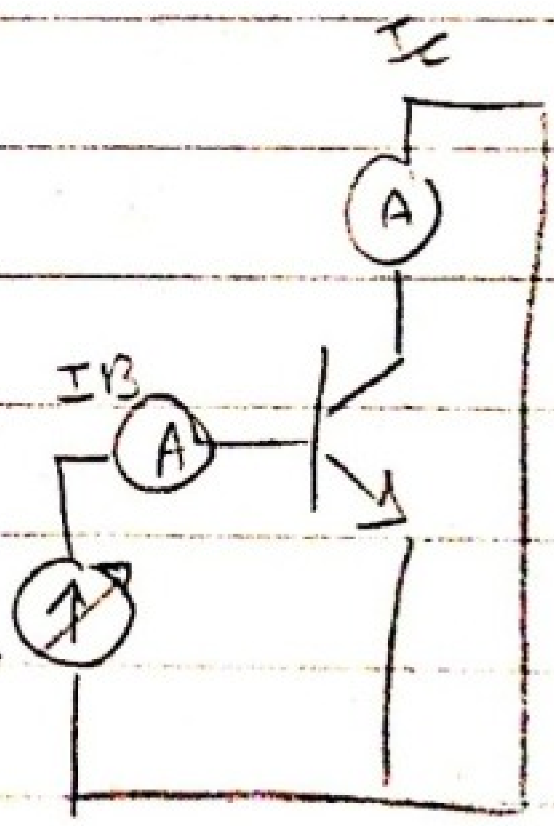
→ DC, low, mid frequency ranges:

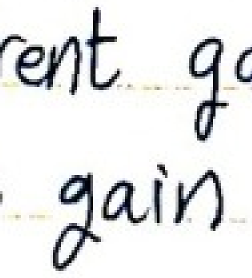
$i_c = \beta i_b$

at high frequency: $i_c = h_{fe}\, i_b$

where h_{fe} : small signal current gain.

or short-cct current gain



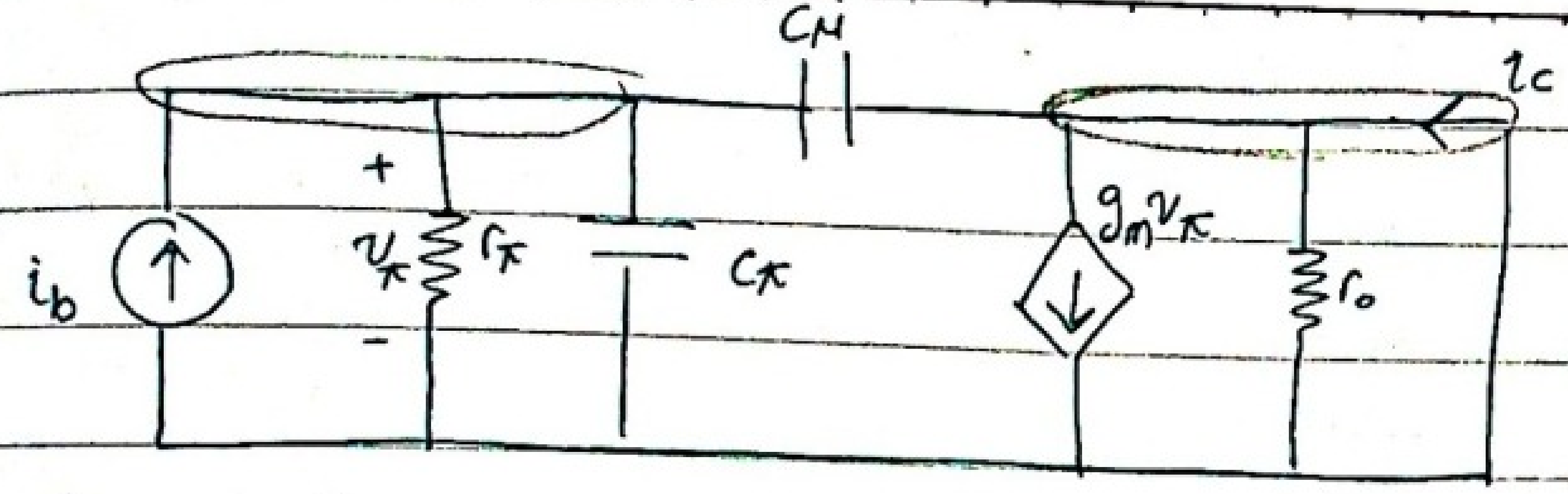


I_B	I_C

$$\beta = \frac{\Delta I_C}{\Delta I_B}$$

$i_c = g_m v_\pi$

27-4/2014 Sun.



$$h_{fe} = \frac{i_c}{i_b}$$

- KCL at the input node:

$$i_b = \frac{v_\pi}{r_\pi} + \frac{v_\pi}{(1/j\omega C_\pi)} + \frac{v_\pi}{(1/j\omega C_\mu)}$$

$$i_b = v_\pi\left(\frac{1}{r_\pi} + j\omega(C_\pi + C_\mu)\right) \longrightarrow (1)$$

- KCL at the output node:

$$g_m v_\pi = i_c + \frac{v_\pi}{(1/j\omega C_\mu)}$$

$$v_\pi = \frac{i_c}{(g_m - j\omega C_\mu)} \longrightarrow (2)$$

Sub (2) in (1):-

$$h_{fe} = \frac{g_m - j\omega C_\mu}{\frac{1}{r_\pi} + j\omega(C_\pi + C_\mu)} = \frac{i_c}{i_b}$$

27-4/2014 Sun.

for typical values :-

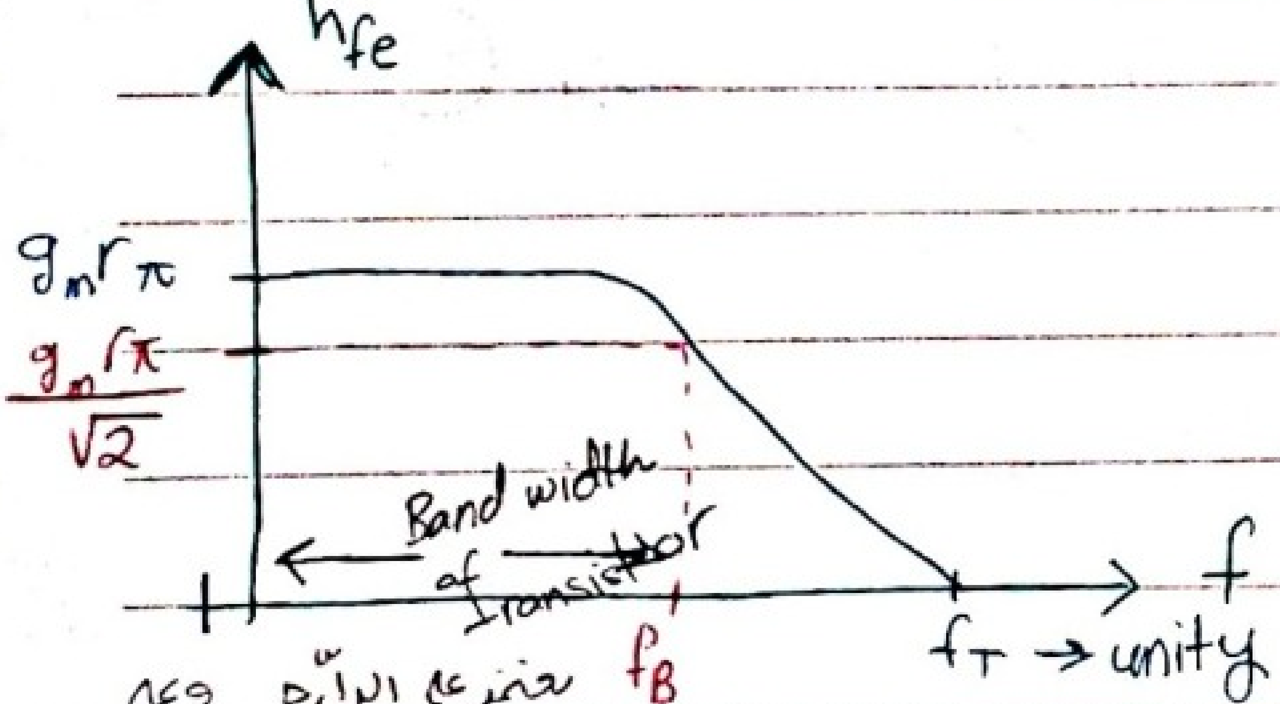
$C_\mu = 0.2\ pf$

$g_m = 50\ mA/V$

$f_{max} = 100\ MHz$

$\Rightarrow \omega C_\mu \ll g_m$

So, $\boxed{h_{fe} \simeq \dfrac{g_m r_\pi}{1 + j\omega r_\pi (C_\pi + C_\mu)}} \simeq k \dfrac{1}{1+s\tau}$



ال freq اللي ال gain عنده = 1

$f_T \rightarrow$ unity gain bandwidth

بتعتمد على الدارة وعلى DC-cct وعلى r_π بتعتمد على i_b I_{CQ}

$f_B \rightarrow$ beta cutoff frequency.

$$f_\beta = \frac{1}{2\pi\tau} = \frac{1}{2\pi r_\pi (C_\pi + C_\mu)}$$

- f_T ?!

$$|h_{fe}(f_T)| = 1$$

$$\left| \frac{g_m r_\pi}{1 + j\left(\frac{f_T}{f_B}\right)} \right| = 1$$

27-4/2014 Sun.

$$\frac{g_m r_\pi}{\sqrt{\cancel{1} + \left(\frac{f_T}{f_\beta}\right)^2}} = 1$$

- $j\frac{f_T}{f_\beta} = j\frac{f_T}{\frac{1}{2\pi r_\pi (C_\pi + C_\mu)}}$

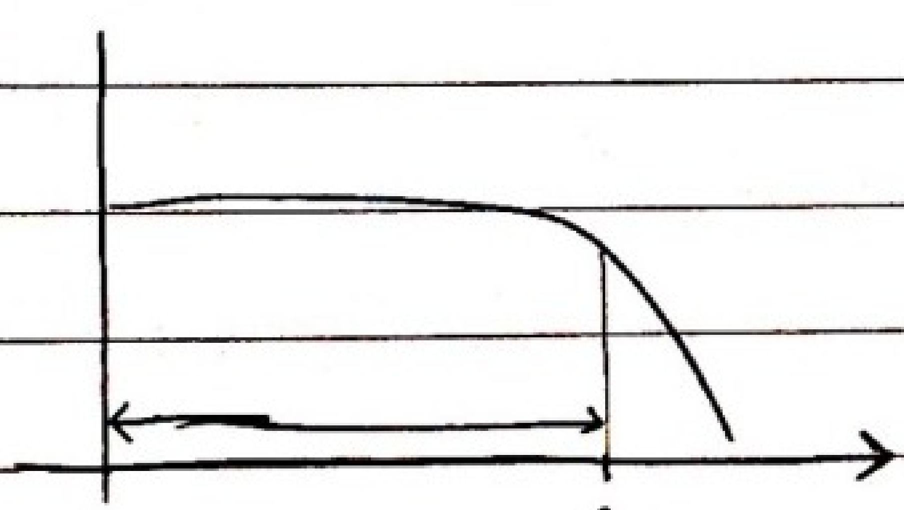
$$= j 2\pi r_\pi (C_\pi + C_\mu) f_T$$

- usually $f_T \gg f_\beta \Rightarrow$

$$\frac{f_T}{f_\beta} = \beta$$

gain * Bandwidth = const

$$\therefore \boxed{f_T = \beta f_\beta}$$



f_β

(Beta - cutoff - freq)

Bandwidth of transistor

small size

$f_\beta \uparrow$

$\Rightarrow C_\mu$ & $C_\pi \downarrow$

29-4/2014 Tue

Example Find the 3dB freq (f_B) of the short cct current gain (h_{fe}) of BJT with $r_\pi = 2.6\ \Omega$, $C_\pi = 2\,pF$

$C_\mu = 0.1\ pF$

$$f_B = \frac{1}{2\pi r_\pi (C_\pi + C_\mu)} = 29.1\ MHz$$

* Example * Find C_π for the BJT given that:

$I_{CQ} = 1\ mA$ $\qquad f_T = 500\ MHz$

$\beta = 100$ $\qquad C_\mu = 0.3\ pF$

$$f_T = \beta f_B \Rightarrow f_B = 5\ MHz$$

$$f_B = \frac{1}{2\pi r_\pi (C_\pi + C_\mu)} \Rightarrow C_\pi = 11.9\ pF$$

$$r_\pi = \frac{\beta V_T}{I_{CQ}} \ ; \ V_T = 0.026\ V$$

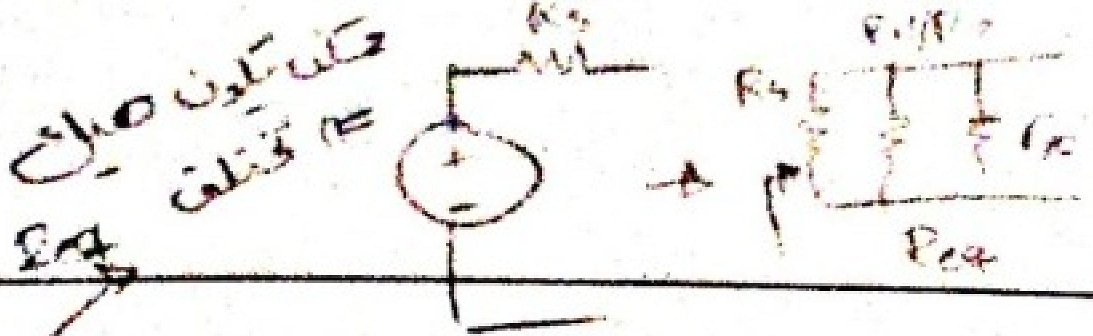
Note:-

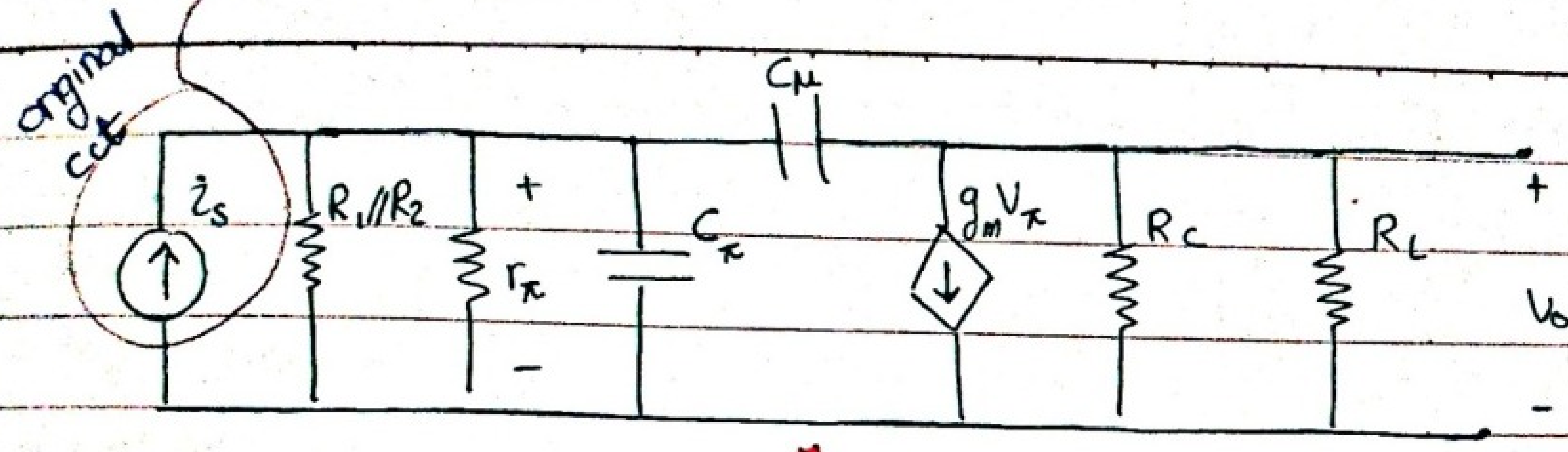
1- $f_T \gg f_B$

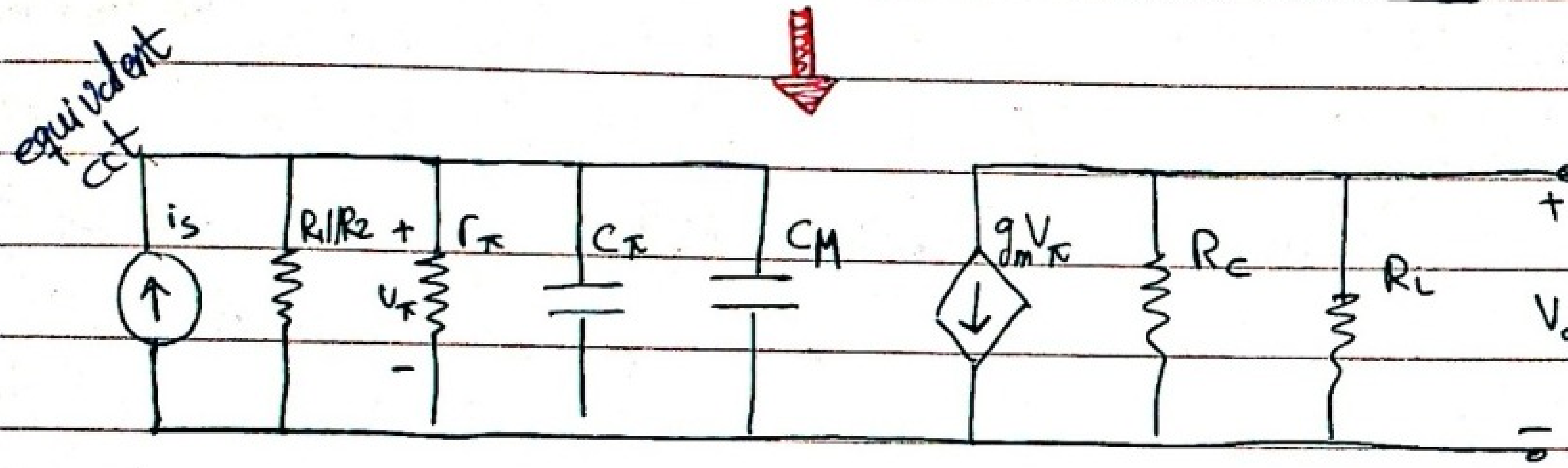
2- $C_\mu \ll C_\pi$

* $C_\mu \ll C_\pi$; But we can't neglect C_μ due to Miller effect.

29-4/2014 Tue.







$$C_M = C_\mu * \left[1 + g_m (R_C // R_L)\right]$$

↳ Miller effect (OR feedback effect)

↓ Miller Capacitance

$$f_{3dB} = \frac{1}{2\pi t}, \quad \tau = R_{eq} C_{eq}$$

Example If $R_C = R_L = 4\,k\Omega$, $r_\pi = 2.6\,k\Omega$
$R_1 // R_2 = 200\,k\Omega$, $C_\pi = 4\,pF$, $C_\mu = 0.2\,pF$
$g_m = 38.5\,mA/v$, Find: f_{3dB} for this cct.

① if we consider the Miller effect:

$$f_{3dB} = \frac{1}{2\pi\tau} = \frac{1}{2\pi R_{eq} C_{eq}}$$

$$= \frac{1}{2\pi (R_1//R_2//r_\pi)(C_\pi + \underbrace{C_M}_{15.6\,pF})} = 3.16\,MHz$$

f_B تعتمد على ال cct الموجود ، وهي Trans. ال تعتمد على f_C

29-4/2014

تقليل ال f_{3dB}

② if we (do not) consider the Miller effect $(C_M = 0)$

$$f_{3dB} = \frac{1}{2\pi (R_1 // R_2 // r_\pi) C_\pi} = 15.5 \ MHz$$

$C_\mu : O.C$

$\rightarrow C_M = C_\mu * (\ldots)$

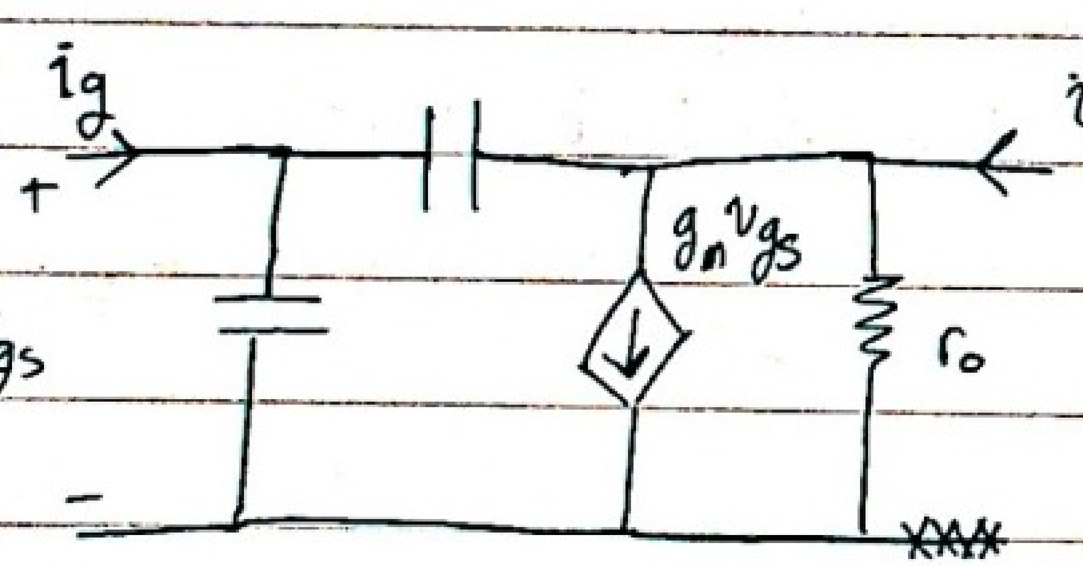
$\Rightarrow C_M = 0$

- $f_{3dB}\Big|_{Miller} \ll f_{3dB}\Big|_{without\ Miller}$

تكلفة زيادة ال Mid

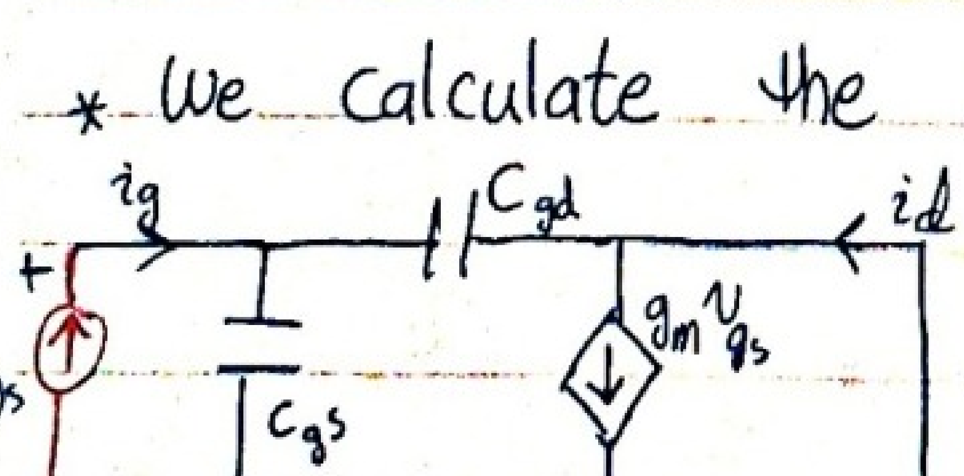
* * * * * *

• FET at high frequency :-



- in DC $\rightarrow I_G = 0$
- low & Midband $\rightarrow I_G = 0$
- high frequency $\rightarrow$?!

* We calculate the short cct current gain:



$$A_i = \frac{i_d}{i_g}$$

29-4/2014 Tue

$$A_i = \frac{i_d}{i_g} = \frac{g_m - j\omega C_{gd}}{j\omega(C_{gs} + C_{gd})}$$

if we consider the typical values $C_{gd} = 0.05\ pF$

$g_m = 1\ mA/V$

$\rightarrow g_m \gg \omega C_{gd}$

$$\boxed{A_i = \frac{g_m}{j\omega(C_{gs} + C_{gd})}}$$

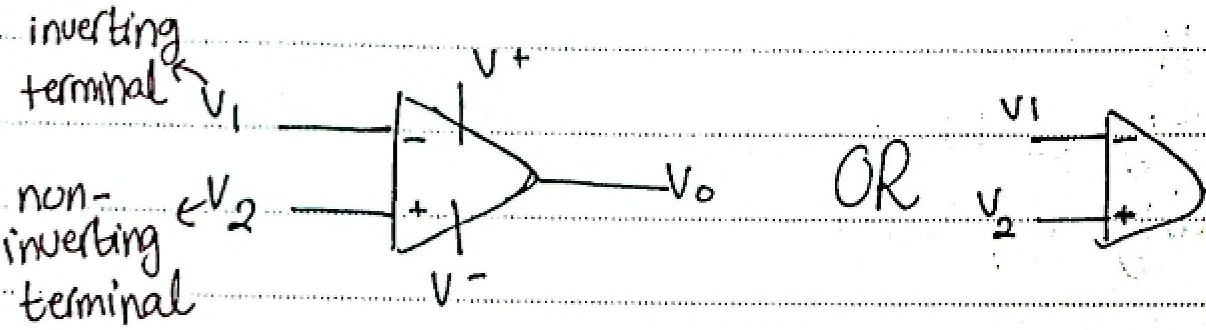
$\rightarrow$ unity gain bandwidth :-

$$f_T = \frac{g_m}{2\pi(C_{gs} + C_{gd})}$$

/ /

• Operational Amplifier (op-amp)

it is an integrated cct (IC) that amplifies the diffrence between two input voltage produces a signal output.



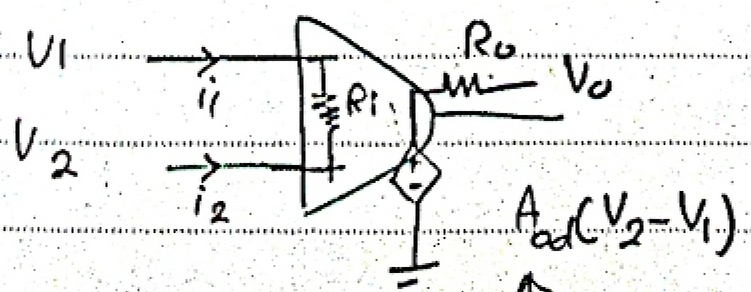
→ the output will have $-V_1$ component and $+V_2$ component.

• Name, why "operational"?

it was used in analog computers to perform mathmatical operations to solve differential and integral equations.

* Ideal op-amp → will be considered usually.
* non-ideal op-amp

• Ideal op-amp:-



↑ open loop differential voltage gain

[1] $R_i = \infty\ \Omega$

[2] $R_o = 0\ \Omega$

[3] $i_1 = i_2 = 0\ A$

[4] $A_{od} = \infty$

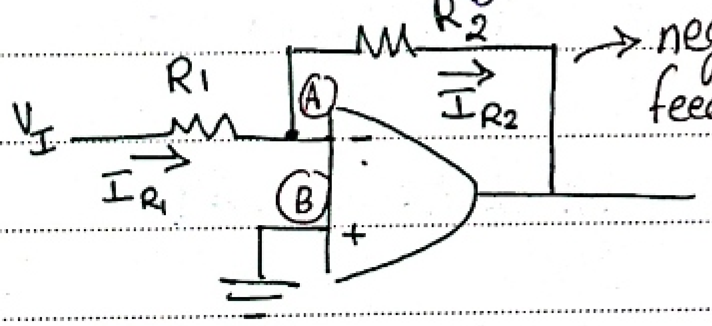
$\Rightarrow V_2 - V_1 = 0$

$\therefore V_2 = V_1$

[5] V_1 and V_2 could be DC or AC, and we need coupling capacitor.

• OP_ amp Applications-

[1] inverting amplifier.



• at A: $V_1 = 0$
$i_1 = 0$

• at B: $V = V_I$
, $I_2 = 0$

$I_{R1} = I_{R2}$

$$\frac{V_I - 0}{R_1} = \frac{0 - V_o}{R_2}$$

$$\rightarrow \frac{V_o}{V_I} = \frac{-R_2}{R_1}$$

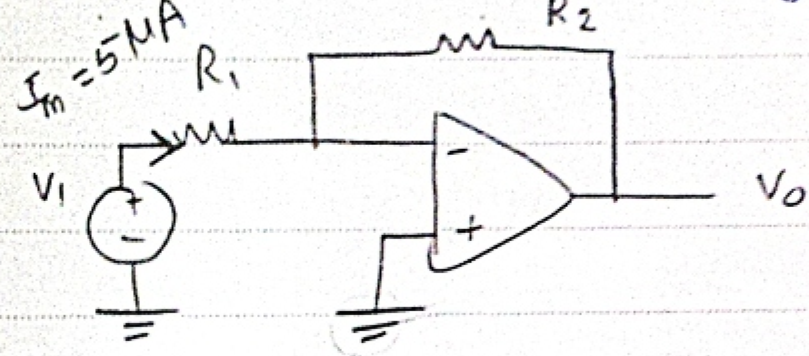
$$v_o = v_I\left(-\frac{R_2}{R_1}\right)$$

* Point A is: a vertual ground cause it gave $V_1 = 0$ & $I_1 = 0$

· feedback:-

negative feedback: it result in stable circuit
positive feedback: it is used to produce oscillators.

Example:- Design an inverting amp. such that the voltage gain $A_v = -5$, knowing that this cct is connected with a src that have $V_s = 0.1 \sin \omega t$ V and this src can supply maximum current of 5 μA.



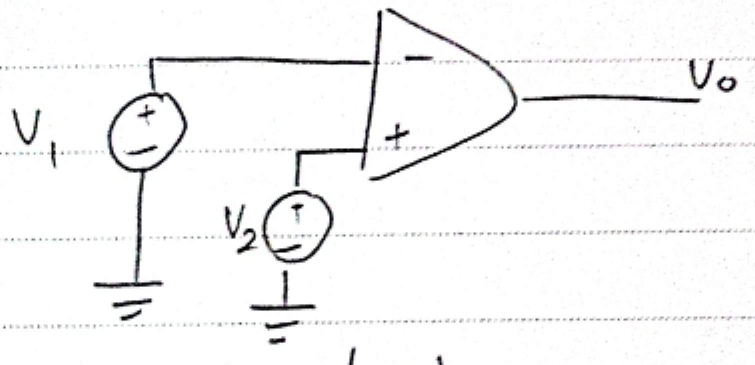
$$A_v = -\frac{R_2}{R_1} = -5$$

$$R_2 = 5R_1$$

$$I_m = \frac{V_{s(max)} - 0}{R_1}$$

$\rightarrow R_1 = 20 k\Omega$

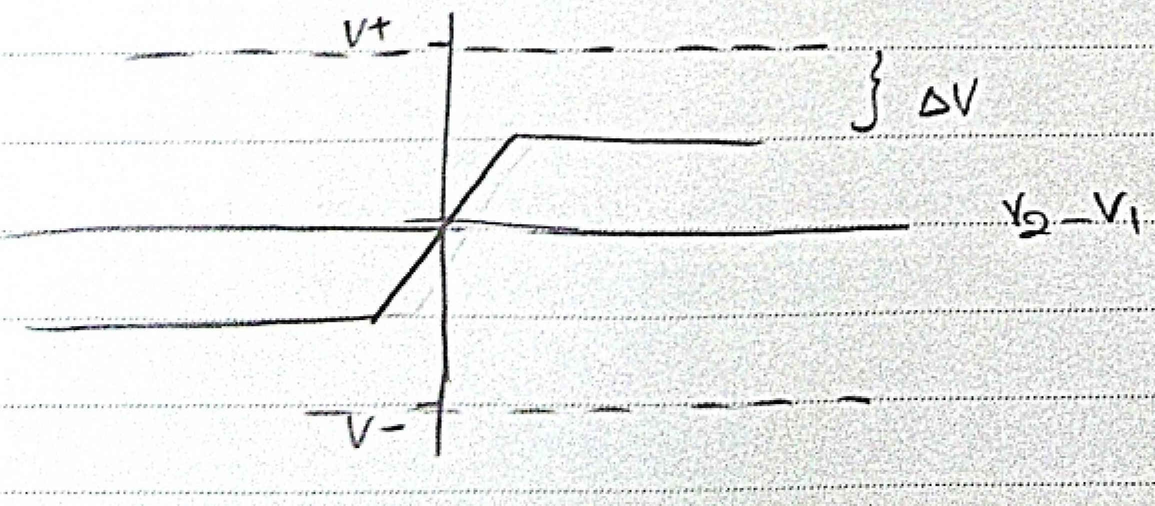
$\therefore R_2 = 100 k\Omega$



(comparator)

if $V_2 > V_1 \rightarrow V_o$ $+V_e$

if $V_2 < V_1 \rightarrow V_o$ $-V_e$



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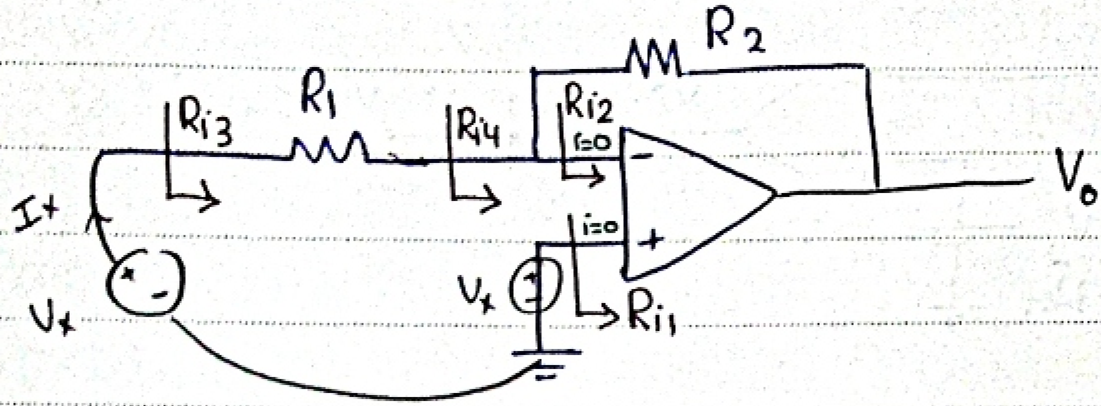
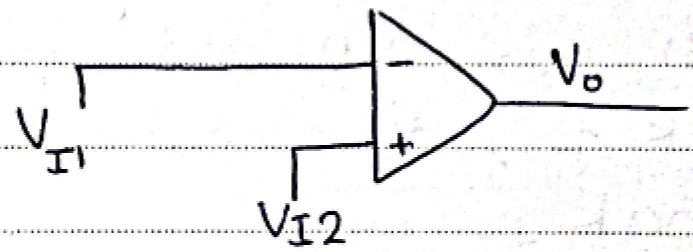


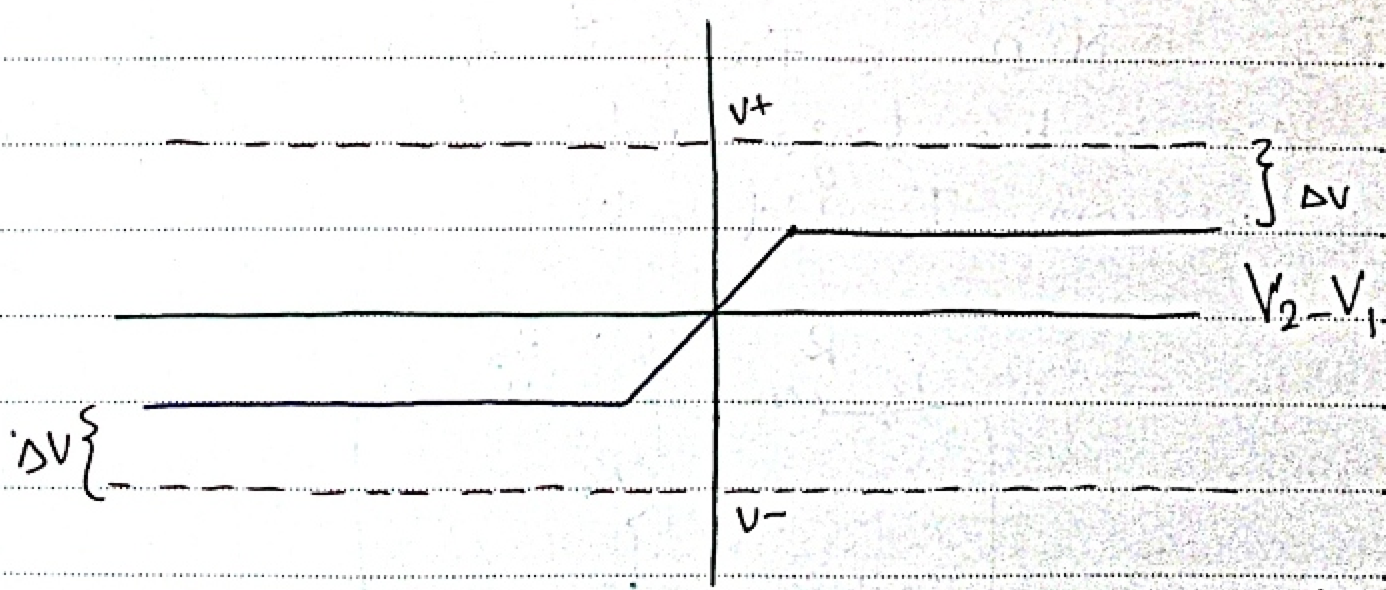
[inverting Amp]

$|Gain| = \left|\frac{R_2}{R_1}\right|$

$$\frac{V_o}{V_i} = \frac{-R_2}{R_1}$$

- $R_{i1} = \infty$
- $R_{i2} = \infty$, $\frac{V_x}{I_x} = \frac{V_x}{0} = \infty$
- $R_{i3} = R_1$
- $R_{i4} = \frac{V_x}{I_x} = 0$

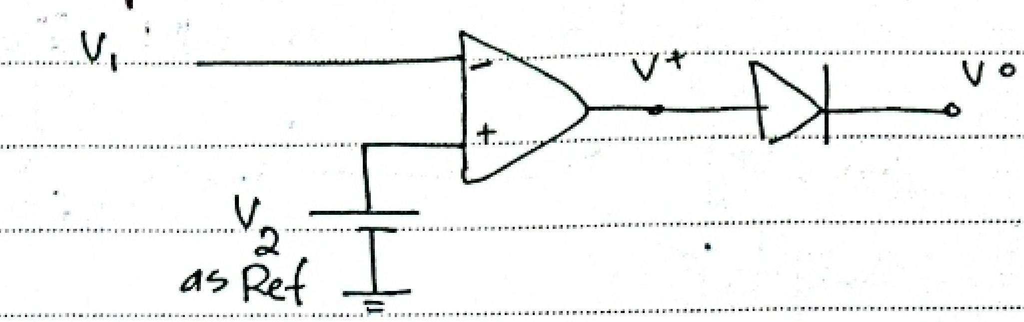




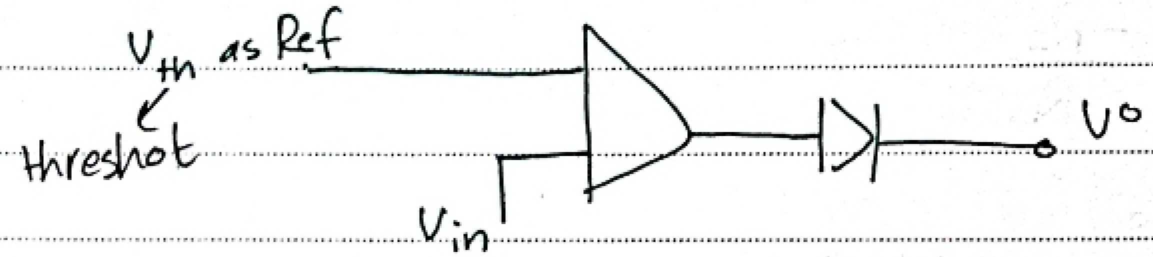
V_o of an op-amp cct is alwayes between

$V^- + \Delta V \leqslant V_o \leqslant V^+ - \Delta V$

* Comparator:-

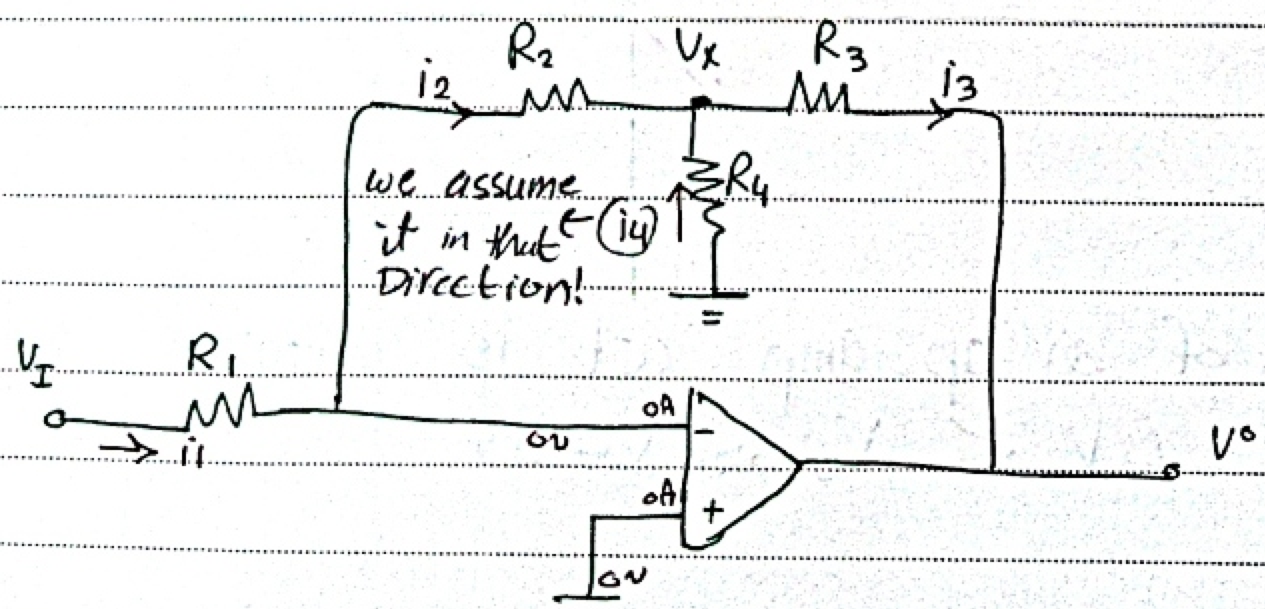


$V_o > 0$
if $V_1 > V_2$



$V_o \rightarrow$ if $V_{in} > V_{th}$
$V_o = 0 \rightarrow$ if
$V_{in} < V_{th}$

• Application:- Amplifier with T- Network.
why do we need T- Network?!
answer: if we want to design an inverting amplifier with $A_V = -100$ and input impedance of $R_i = 50\ k\Omega$, then we need:
$R_1 = R_i = 50\,k\Omega$
$R_2 = 5\ M\Omega$ ← Finding it from the gain.
↳ this is too large value for most practical cct.
⇒ Solution: T - Network



8/5/2014

$i_2 = i_1$

$$\frac{V_I}{R_1} = \frac{0 - V_x}{R_2}$$

$$\rightarrow V_x = \frac{-R_2}{R_1} V_i \longrightarrow ①$$

requirements: Gain ↑, R_i ↑ → loading effect ↓ ∴ R_2 will be ↑

@ node x:

$i_2 + i_4 = i_3$

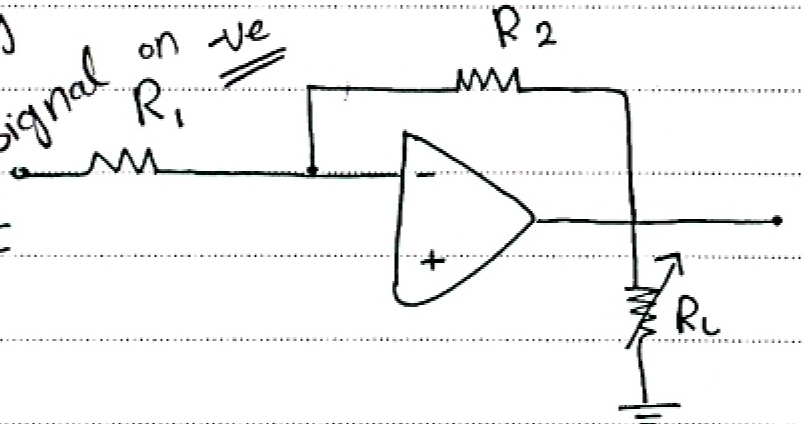
$$-\frac{v_x}{R_2} - \frac{v_x}{R_4} = \frac{v_x - V_o}{R_3}$$

$$v_x = \left(\frac{1}{R_2} + \frac{1}{R_4} + \frac{1}{R_3}\right) = \frac{V_o}{R_3} \rightarrow ②$$

sub ② in ①:

$$A_v = \frac{V_o}{v_i} = \frac{-R_2}{R_1}\left(1 + \frac{R_3}{R_4} + \frac{R_3}{R_2}\right)$$

inverting & input signal on -ve



$\boxed{A_v} = \frac{-R_2}{R_1}$ ↓

will not change with R_L

non-ideal $A_{od} = \infty$ $R_i = \infty$ $R_o = 0$

Ideal op-amp:- it is assumed to simplify the analysis and design non-ideal op-amp but the final will be similar to the non-ideal op-amp.

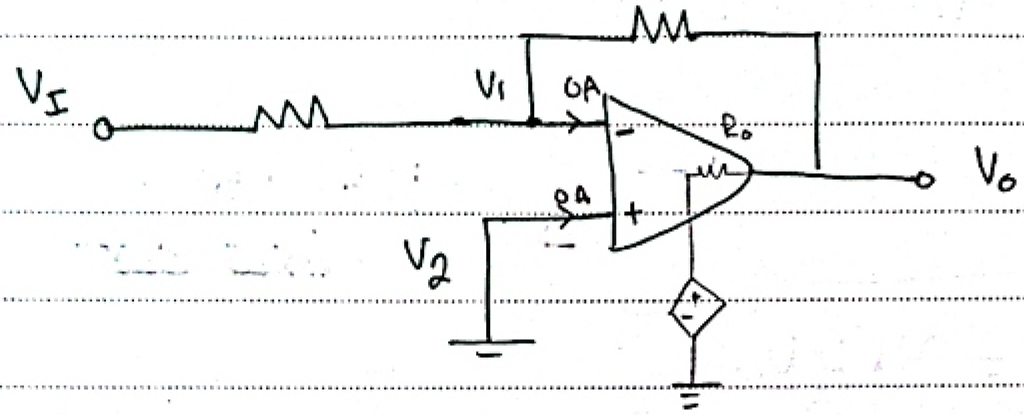
ممكن نحط coupling capacitor at input and output !!

8/5/2014

• Example:- if we assume that $A_{od} \neq \infty$

$\Rightarrow V_2 \neq V_1$ $R_i = \infty$ $R_o = 0$

Find the gain of an inverting amp:-



neither completely ideal nor non-ideal.

$R_i = 0 \rightarrow i_1 = i_2 = 0$

$i_{R_1} = i_{R_2}$

• $\dfrac{V_I - V_1}{R_1} = \dfrac{V_1 - V_o}{R_2} \rightarrow \boxed{1}$

• $V_o = A_{od}(V_2 - V_1) = -A_{od} V_1$

$\rightarrow V_1 = \dfrac{-V_o}{A_{od}}$

Sub ② in ①

$A_v = \dfrac{-R_2}{R_1} \dfrac{1}{\left(1 + \frac{1}{A_{od}}\left(1 + \frac{R_2}{R_1}\right)\right)}$

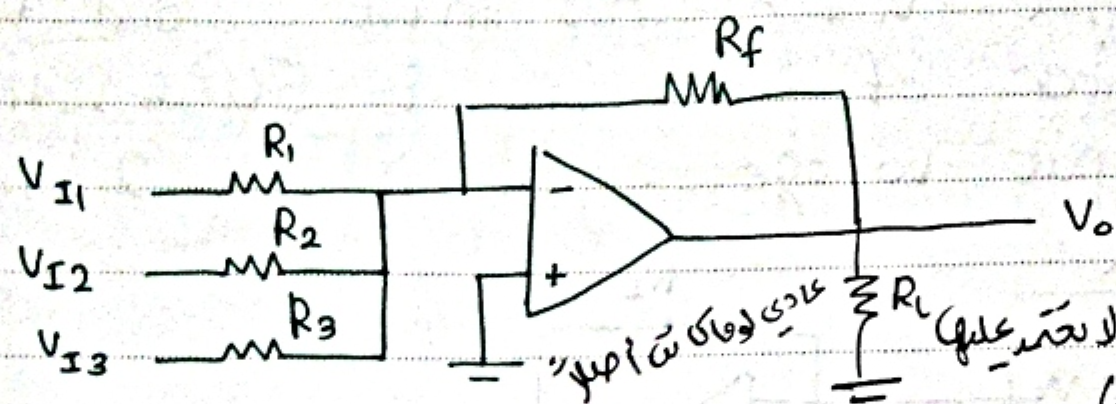
if $R_2 = 100\,k\Omega$ $R_1 = 10\,k\Omega$

	A_{od}	A_v
	10^2	-9.01
non-ideal	10^3	-9.89
	10^4	-9.989
	10^5	-9.999
	10^6	-9.9999
ideal case	∞	-10

→ the same result.

11 / 5 / 2014

- summing amplifier:

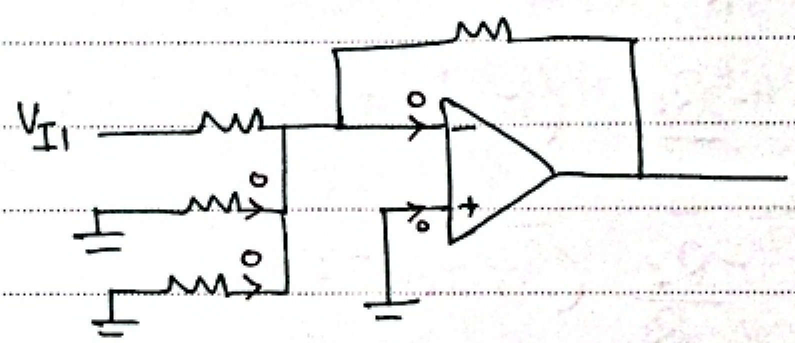


"عادي لو كانت = صفر"

قيمة ال gain لا تعتمد عليها "fixed Gain"

use super position techneque:-

$V_o' = V_o$ due to V_{I1} only:-



$$\therefore \quad V_o' = \frac{-R_f}{R_1} * V_{I1}$$

$$V_o'' = \frac{-R_f}{R_2} * V_{I2}$$

$$V_o''' = \frac{-R_f}{R_3} * V_{I3}$$

$$\therefore V_{total} = -R_f\left(\frac{V_{I1}}{R_1} + \frac{V_{I2}}{R_2} + \frac{V_{I3}}{R_3}\right)$$

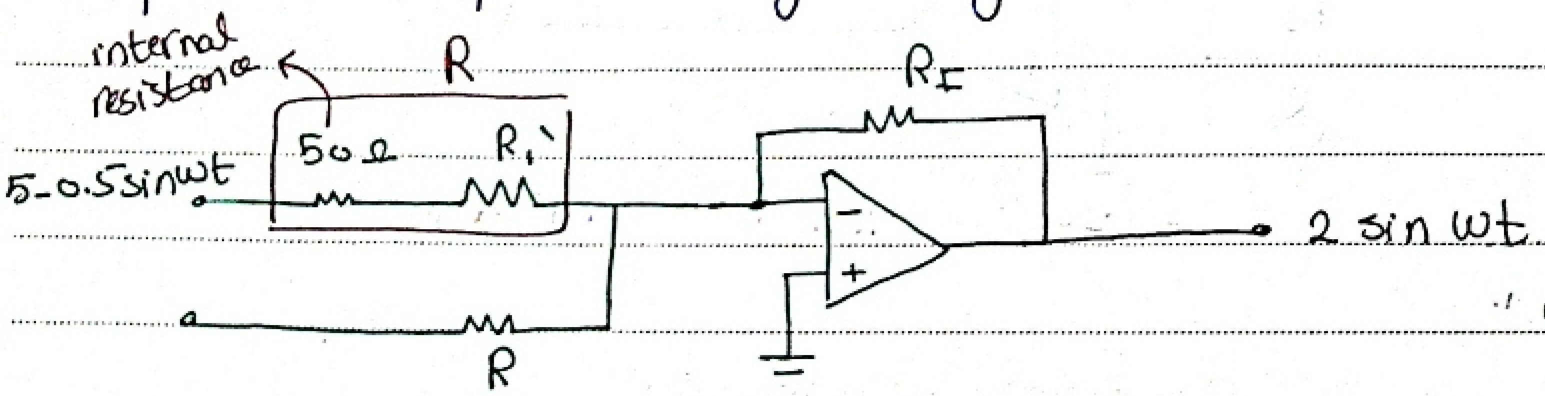
if $R_1 = R_2 = R_3 = R$

$$\rightarrow V_o = \frac{-R_f}{R}\left(V_{I1} + V_{I2} + V_{I3}\right)$$

$V_o = -(V_{I1} + V_{I2} + V_{I3})$: just if all Resistors are equal to each other

11 / 15 / 2014

- Example:- Design a summing Amplifier that has an input signal $V_i = 5 - 0.5 \sin wt$ and the internal resistor of the source is $50\ \Omega$, the required output voltage signal is $V_o = 2 \sin wt$



$$V_o = \frac{-R_f}{R}(V_{I1} + V_{I2})$$

$$2 \sin wt = \frac{-R_f}{R}(5 - 0.5 \sin wt + V_{I2})$$

$$2 \sin wt = \frac{-R_f}{R}(5 - 0.5 \sin wt + (-5))$$

$$2 = \frac{-R_f}{R}(-0.5)$$

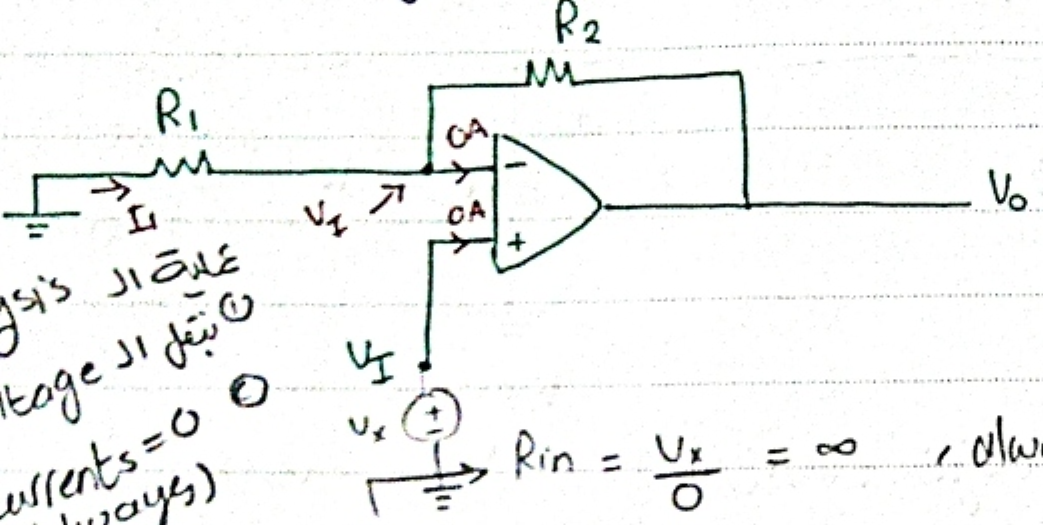
$$\Rightarrow \frac{R_f}{R} = 4 \Rightarrow \boxed{R_f = 4R}$$ ∴ any two values verified this ratio.

let $R_f = 120\ k\Omega \rightarrow R = 30\ k\Omega$

$R_i' = 30 k\Omega - 50\ \Omega$

11 / 15 / 2014

• Non-inverting amplifier :-



عملية ال analysis
① نتقل ال voltage
② currents = 0 (always)

$R_{in} = \frac{v_x}{0} = \infty$, alwayes $= \infty$

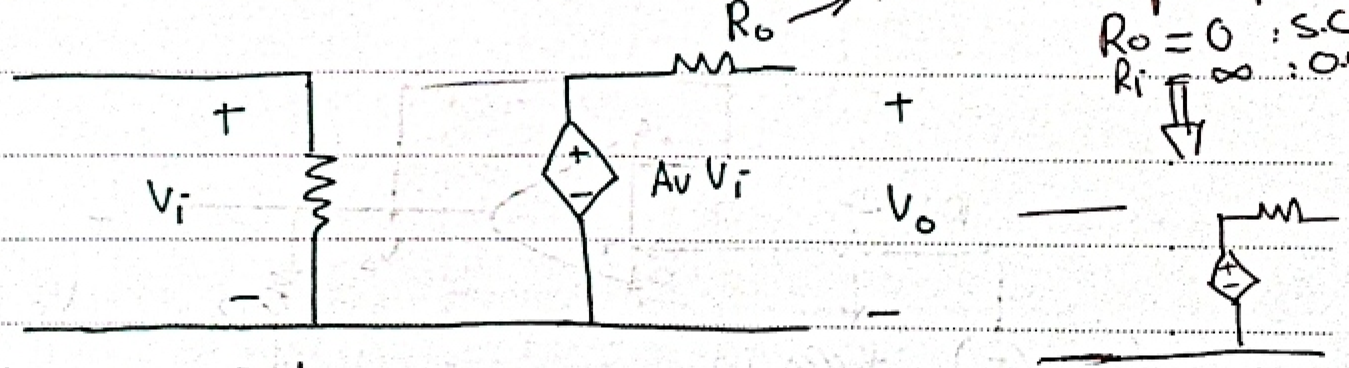
$$I_1 = I_2$$

$$\frac{0 - V_I}{R_1} = \frac{V_I - V_o}{R_2}$$

$$A_v = \frac{V_o}{V_I} = 1 + \frac{R_2}{R_1} \quad (\text{Here} > 1)$$

• Equivalent two-port Network of non-inverting amplifier

$R_o \rightarrow$ for ideal op-amp
$R_o = 0$: S.C
$R_i = \infty$: O.C



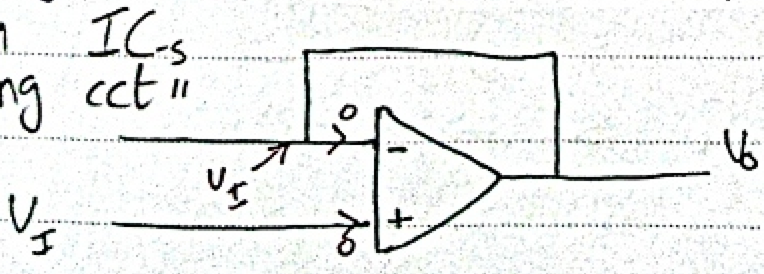
$A_v < 1$ when $R_2 < R_1$!

• يلغي تأثير ال loading effect
• تنشئ ال V بغض النظر عن آثار R_L

output follows V_I { mag, phase.

• voltage follower (Buffer / impedance transformer)

using in ICs "integrating cct"



$$A_v = \frac{V_o}{V_I}$$

$$A_v = 1$$

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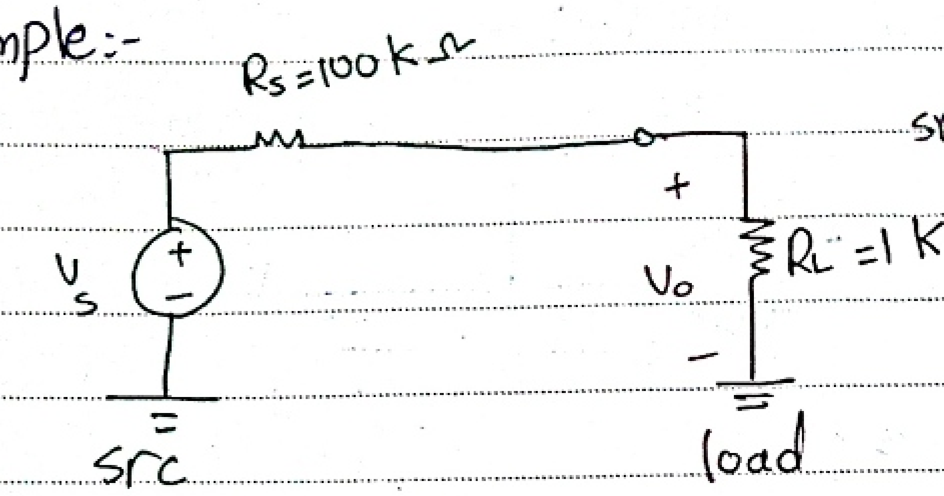
• Example:-



ال load مسئول مع src without using Buffer.

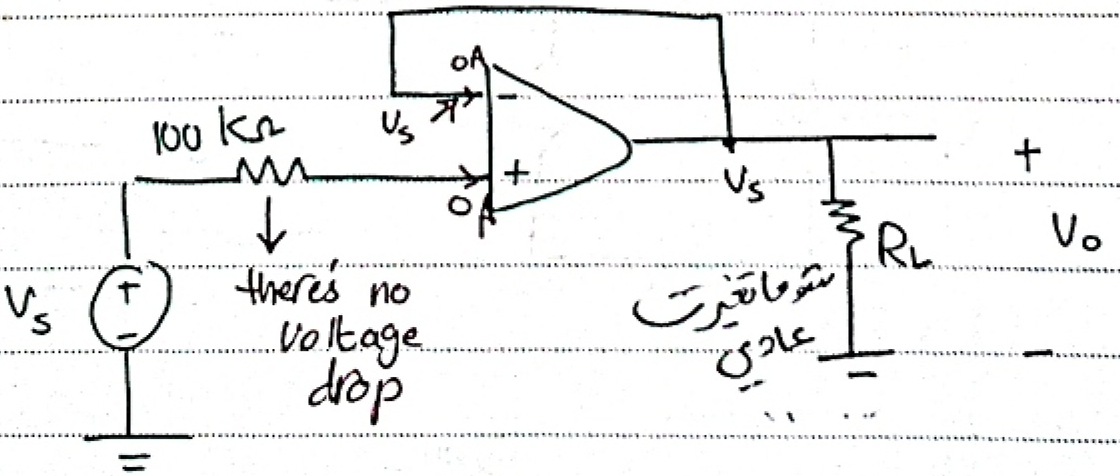
using voltage division: $V_o = V_s * \frac{1}{1+100}$

⇒ $\boxed{\text{High}}$ loading effect
problem.

But without loading effect (without load) →
$V_o = V_s$

⇒ with load V_o changed.

to solve this problem using Buffer



→ $V_o = V_s$ "no loading effect"

if R_L : SC → $V_o = 0$

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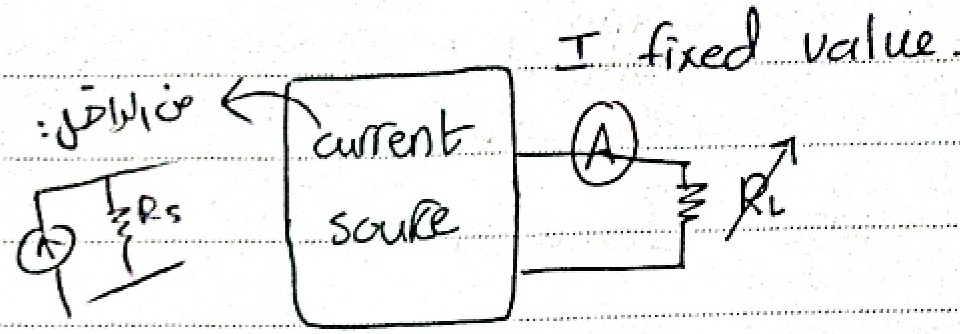
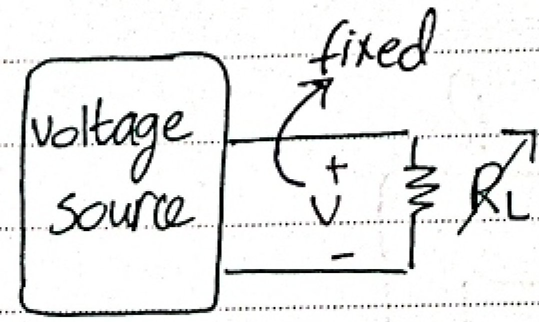
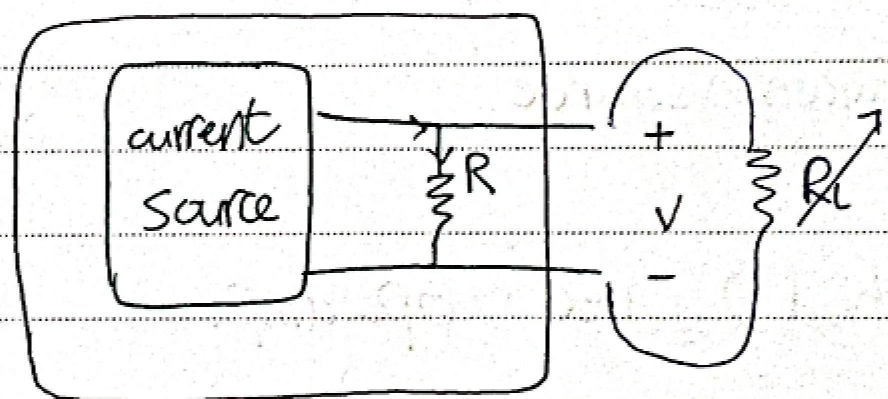
- current - to - voltage converter:-





→ current to voltage convertor:-

* Method: use R.



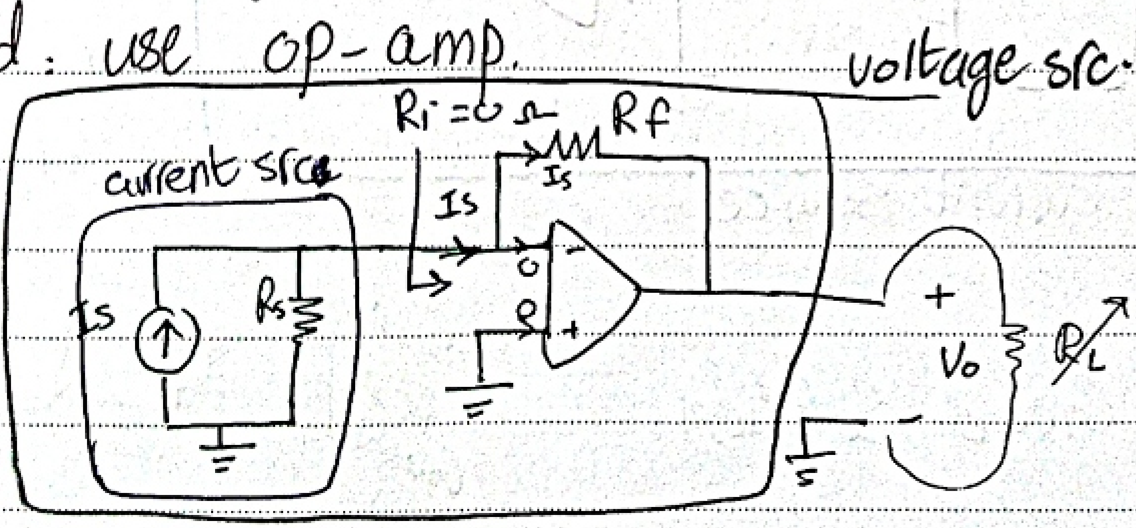
voltage source

V will change with R_L so it is bad solution.

R_s ما إلها دور ، أو تأثير مهمل

* Method: use op-amp.

R_s internal Resistor of the source



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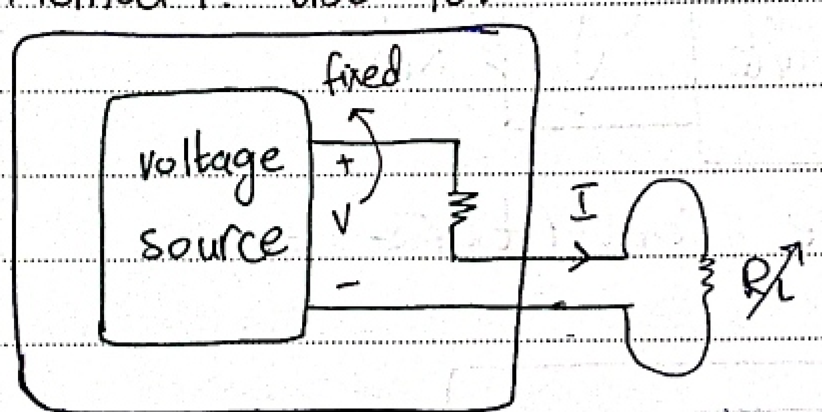
$$I_s = \frac{0 - V_o}{R_f} \rightarrow V_o = -R_f I_s$$

V_o ↓ fixed independent ON R_L

→ Good Solution.

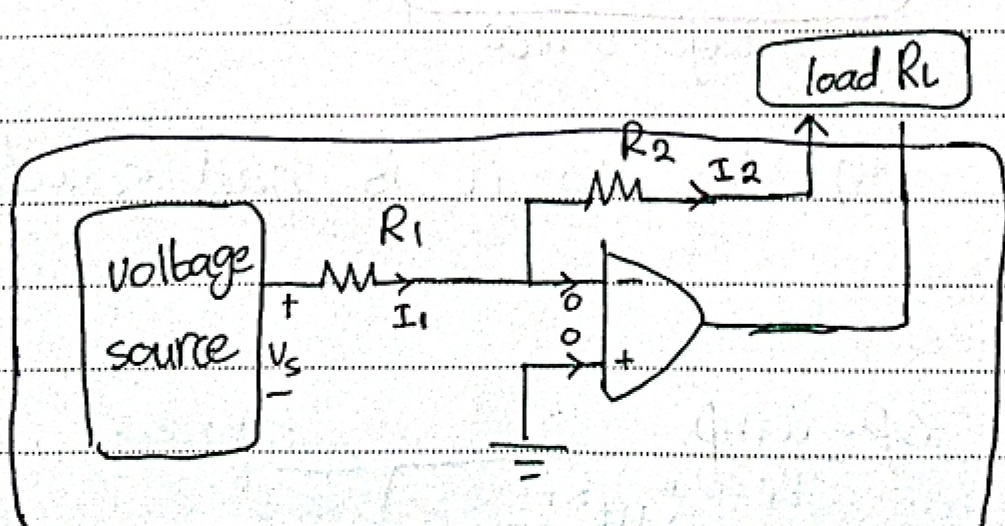
* Voltage-to-current inverter:-

. Method 1: use R:



→ Bad solution since I changes with R_L

. Method 2: use op-amp:



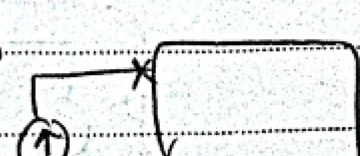
$$\rightarrow I_2 = I_1 = \frac{V_s}{R_1}$$

I_2 fixed (V_s/R_1 fixed)

I_2 fixed, ind. on R_2

→ Good Solution.

لا تصلح إذا R_L تكون Grounded:



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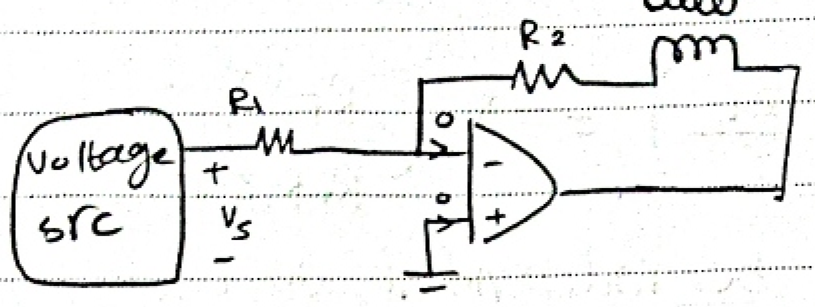
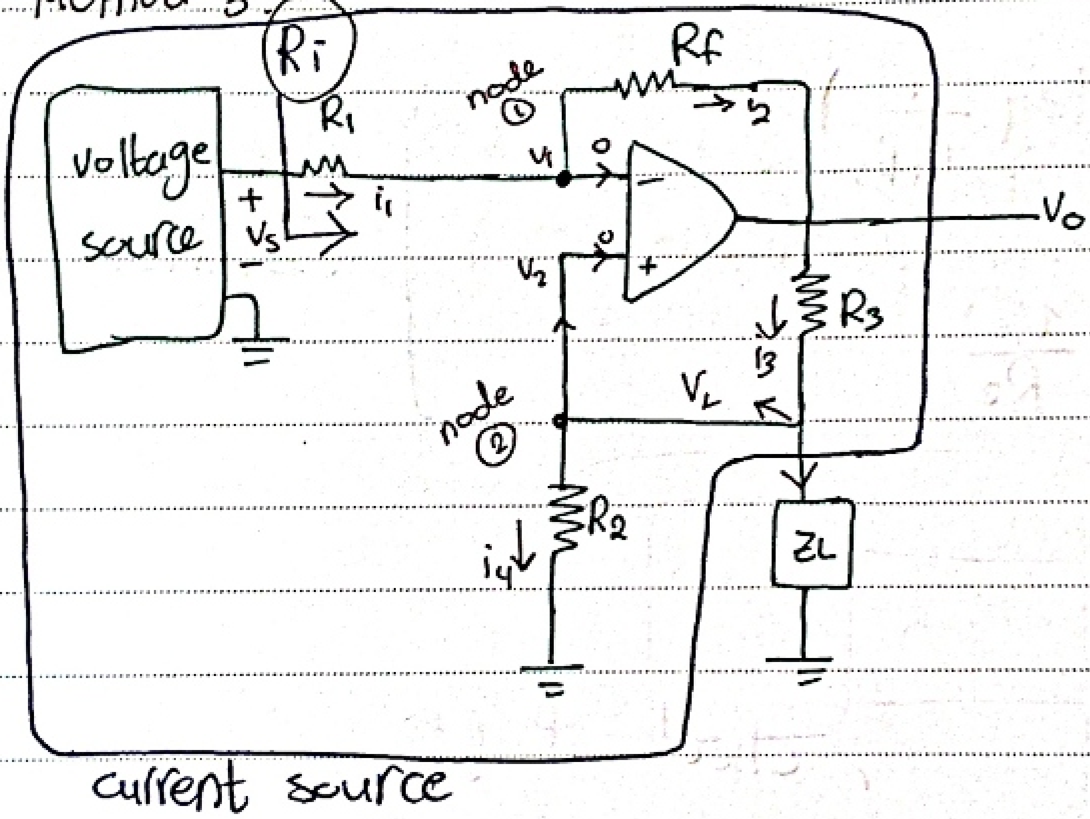
- But R_L should not be grounded

Disadvantage.



مع افتراض تحقيق الشرط ?!
ع معرفة ال i_L

Method 3:



$\rightarrow V_1 = V_2 = V_L = i_L Z_L$

$\rightarrow i_1 = i_2$ from node (1)

$$\frac{v_s - i_L Z_L}{R_1} = \frac{i_L Z_L - v_o}{R_f} \rightarrow \boxed{1}$$

(نبي نطلع v_o بدلالة i_L)

$\rightarrow i_3 = i_L + i_4$ from node (2)

$$\frac{V_o - i_L Z_L}{R_3} = i_L + \frac{i_L Z_L}{R_2} \rightarrow \boxed{2}$$

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use $\boxed{1}$ and $\boxed{2}$:-

$$i_L\left(\left(\frac{R_F Z_L}{R_1 R_3}\right) - 1 - \frac{Z_L}{R_2}\right) = v_s\left(\frac{R_F}{R_1 R_3}\right)$$

→ we need i_L to be independent on Z_L →

$$\boxed{\frac{R_F}{R_1 R_3} = \frac{1}{R_2}}$$

لازم أتأكد من القيم مو بس من الشكل!

→ $i_L = -v_s\left(\frac{R_f}{R_1 R_3}\right)$

(current fixed, independent on Z_L)

→ $i_L = -\frac{v_s}{R_2}$

Good Solution.

→ Finding R_i :

$$R_i = \frac{R_1 R_2}{R_2 + Z_L}$$, check it !?

مو شرط بكل cct تكون هادي القيمة.

$\boxed{op\text{-}amp}$: $V_o = A_{od}(V_2 - V_1)$

شو الفرق ج.إ

هون بتحكم بقيمة الـ gain

/ /

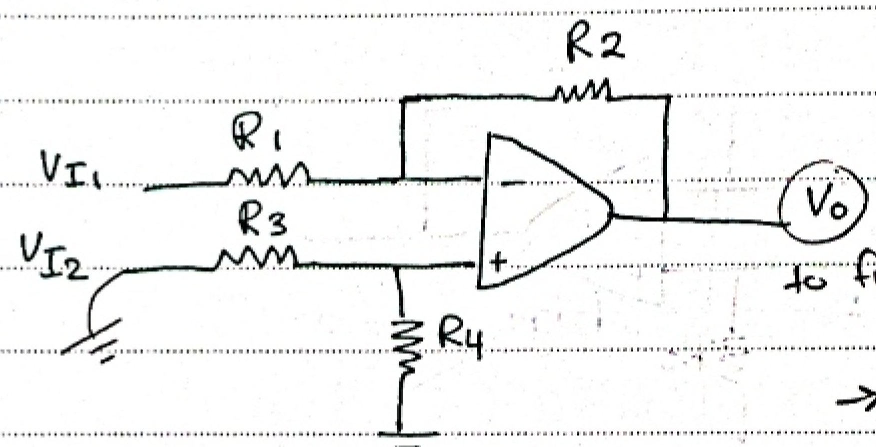
ما بقدر اتحكم بقيمتها فيعتمد على الـ A_{od} الداخلية

* Diffrence Amplifier:- → to take the diffrence between two voltages and amplify it.

$V_o = A_{od}(V_2 - V_1)$

ما بقدر اتحكم بـ cct من الداخل

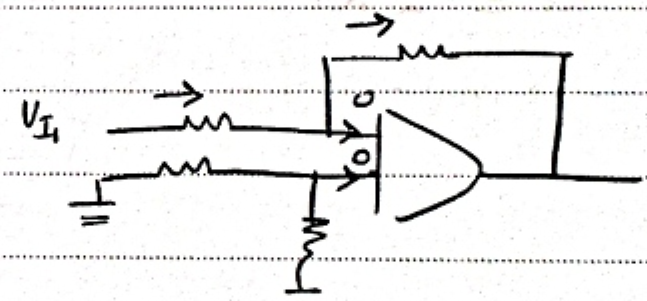
V_{I_2} V_{I_1}



to find it with r.to V_{I_1} & V_{I_2} → using super position.

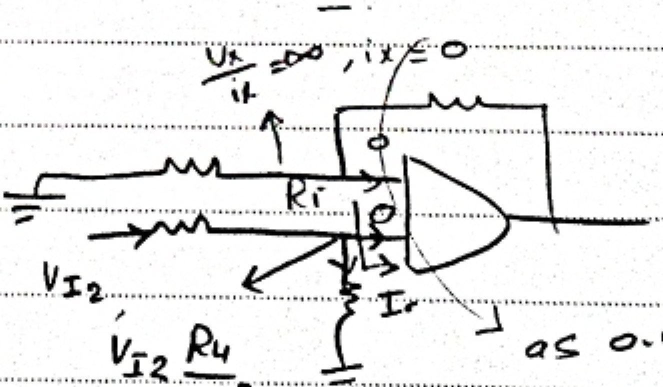
• By super position:-

$$V_o' = \frac{-R_2}{R_1} V_{I_1}$$



$$V_o'' = \left(1 + \frac{R_2}{R_1}\right)\left(\frac{R_4}{R_4 + R_3}\right) V_{I_2}$$

inverting - amp.



$$\rightarrow V_o = \frac{-R_2}{R_1} V_{I_1} + \left(1 + \frac{R_2}{R_1}\right)\left(\frac{R_4}{R_4 + R_3}\right) V_{I_2}$$

→ voltage division between R_3 & R_4

$$V_o = \left(1 + \frac{R_2}{R_1}\right)\left(\frac{R_4/R_3}{1 + R_4/R_3}\right) V_{I_2} - \frac{R_2}{R_1} V_{I_1}$$

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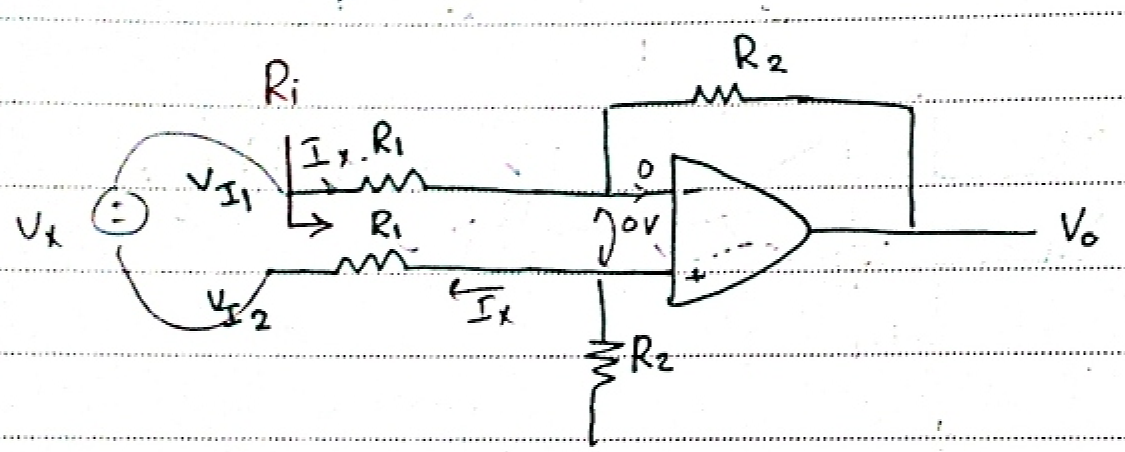
• if $V_{I_1} = V_{I_2}$ then V_o should be = zero

So $\frac{R_2}{R_1} = \frac{R_4}{R_3}$

موشرط بس دريهم الشرط بس يساوى ال Ratio بس للتسهيل

$$\therefore \boxed{V_o = \frac{R_2}{R_1}\left(V_{I_2} - V_{I_1}\right)}$$



$R_i = 2R_1$

$-v_x + R_1 I_x + R_1 I_x + 0 = 0$

$2R_1 = \frac{v_x}{I_x}$

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* Instrumentation Amplifier:-

we know that for difference amplifier:-

- Gain $= \frac{R_2}{R_1}$
- $R_i = 2R_1$

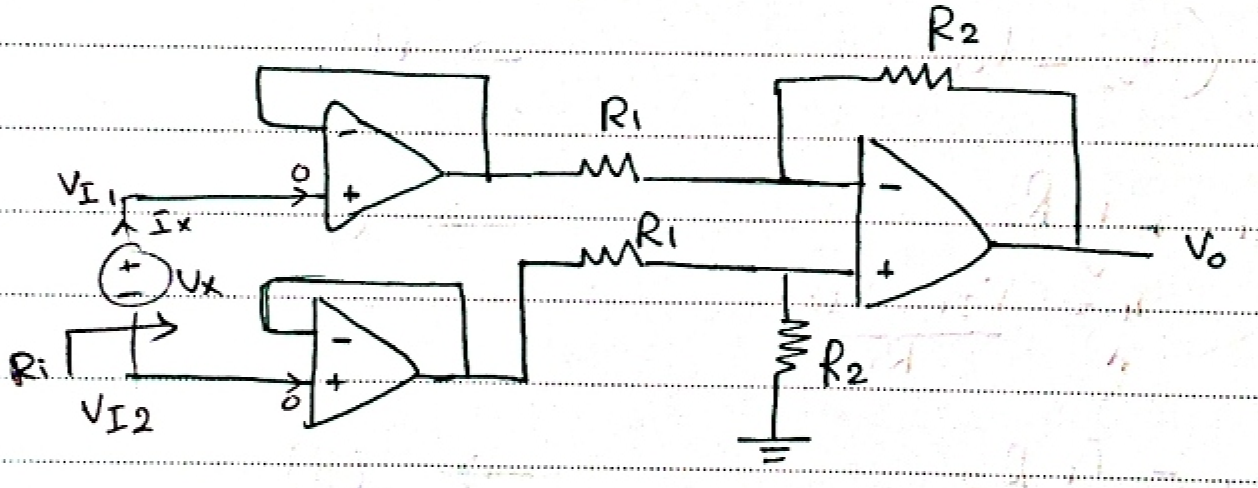
بدي R_i عالية ← loading effect قليل

و Gain بدي اتحكم فيه ,!

! Gain $\downarrow$ ⇐ $\uparrow R_1$ ⇐ $\uparrow R_i$

→ problem:- Both R_i and gain are dependent on R_1

→ solution:- ① use Buffer.



⇒ $\boxed{R_i = \infty}$

⇒ But there is another problem!
if we need to change the gain we have to change two resistor.

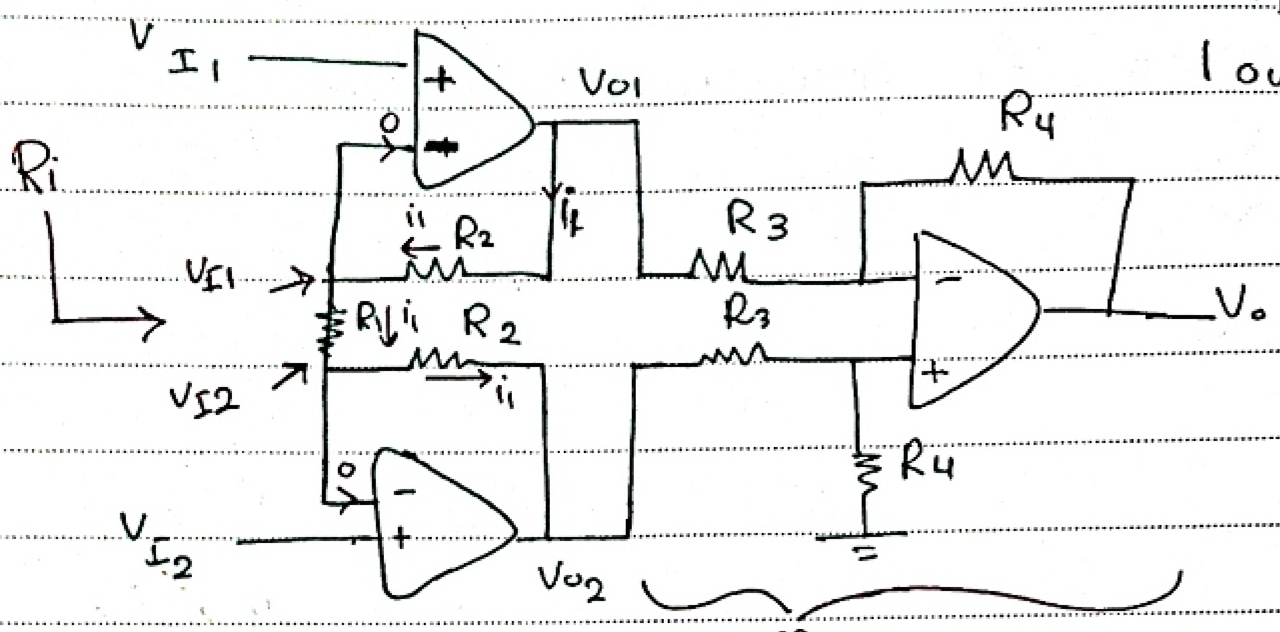
صعب على ال user يغير ال 2-resistor ← using potentiometer
بنفس المقدار.

the change must be equally → This is a practical problem.

/ /

② : using Instrumentation Amplifier.

2 inputs
1 output



Difference Amp → الشرط إنه متحقق

$$V_o = \frac{R_4}{R_3}\left(V_{o2} - V_{o1}\right) \rightarrow ①$$

$$V_{o1} = V_{I1} + i_1 R_2 \rightarrow ②$$

$$i_1 = \frac{V_{I1} - V_{I2}}{R_1}$$

$$V_{o2} = V_{I2} - i_1 R_2 \rightarrow ③$$

use ② and ③ in ①:-

$$V_o = \frac{\overset{\text{fixed}}{R_4}}{\underset{\text{fixed}}{R_3}}\left(1 + \frac{2\overset{\text{fixed}}{R_2}}{R_1}\right)\left(V_{I2} - V_{I1}\right)$$

R_1 متغيرة.

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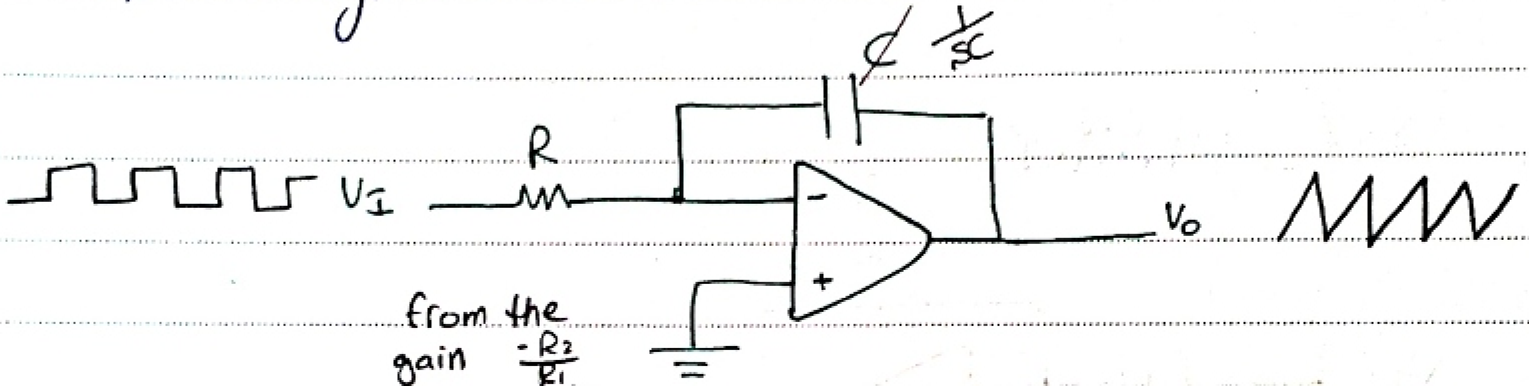
- advantages:-

1. $R_i = \infty$
2. The gain can be changed using one resistor (R_1)

* Integrator:-



from the gain $\frac{-R_2}{R_1}$

$R_2 \to Z_c$

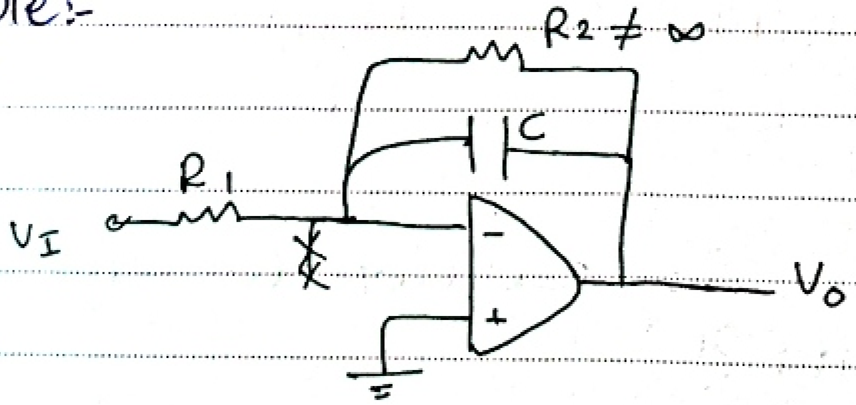
- $V_o(S) = V_I(S) * \left(\frac{-Z_c}{R}\right) = -\frac{1}{SRC} \cdot V_I(s)$ (S-domain)

output = input * T.F

T.F : Transfer function → Gain

- $V_o(s) = V_c(0) - \frac{1}{RC}\int_0^t v_I(t')\,dt'$ (time-domain)

- Example:-



- what is the condition for making this cct an integrator

$$V_o(S) = -\frac{R_2 /\!/ \frac{1}{sC}}{R_1} V_I(S) = \frac{-R_2}{R_1} \cdot \frac{1}{1 + R_2CS} V_I(S)$$

$$\left(\frac{-R_2}{R_1} \cdot \frac{1}{1+R_2CS}\right) \approx \left(-\frac{1}{SRC}\right)$$ بدي الـ 2-terms يشبهو بعض

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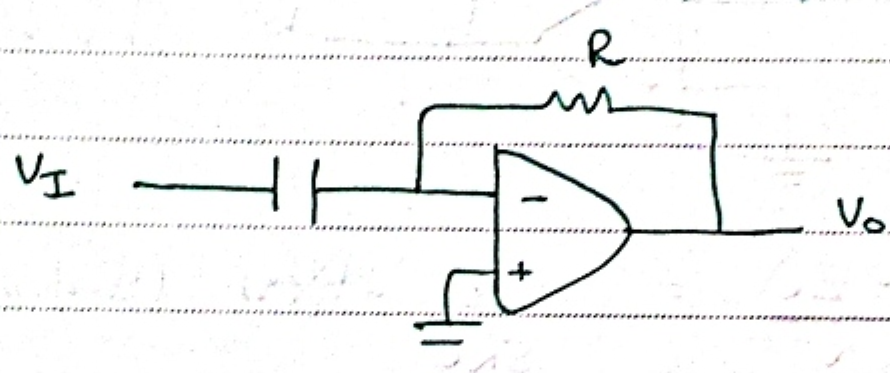
→ the condition: $R_f C S \gg 1$

$S \rightarrow j2\pi f$

* $\frac{-R_f}{R_1} \cdot \frac{1}{R_f C S} = \frac{-1}{R_1 C S}$ #

⇒ this cct can be used as integrator at high frequency.

* differentiator:- C ← R ومكان R ← C مكان



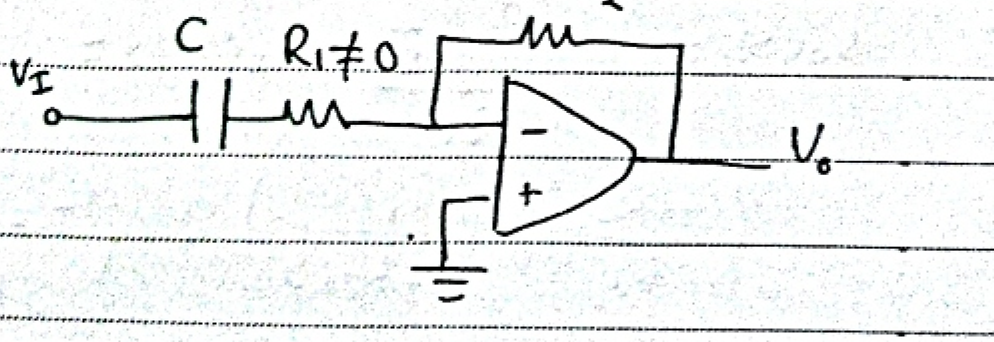
. S-Domain: $V_o(S) = \frac{-R}{(1/SC)} V_I(S)$

$$V_o(S) = -RCS\ V_I(S)$$

. time-Domain: $V_o(t) = -RC \frac{d V_I(t)}{dt}$

Example:- what is the condition to make this cct a differentiator?!

$V_o = \frac{-R_2}{R_1 + \frac{1}{SC}} V_I(S)$



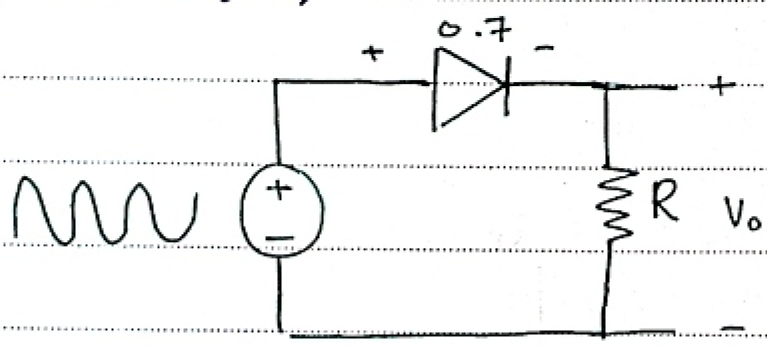
$V_o(S) = \frac{-R_2\ SC}{SCR_1 + 1} V_I(S)$

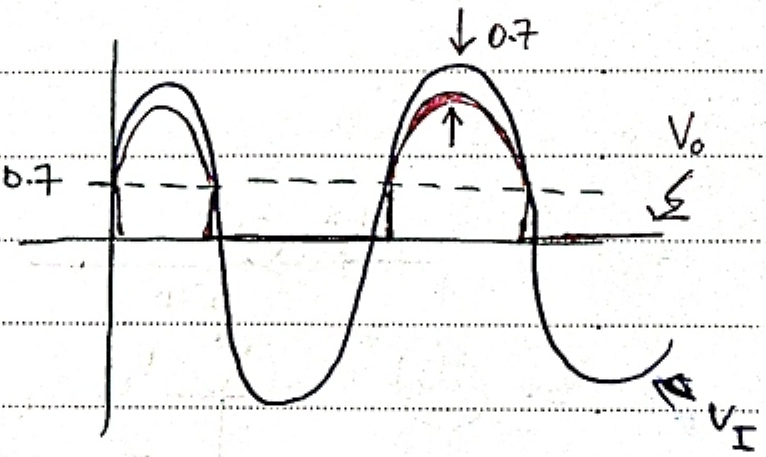
→ $SCR_1 \ll 1$

⇒ this cct can be used as differentiator at Low frequency.

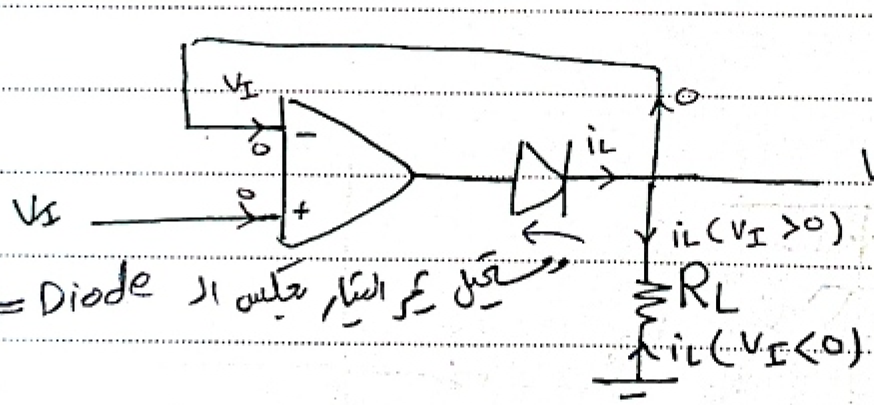
* Precision half-wave rectifier :-

→ we know that, the diode rectifier, the voltage in should be > 0.7

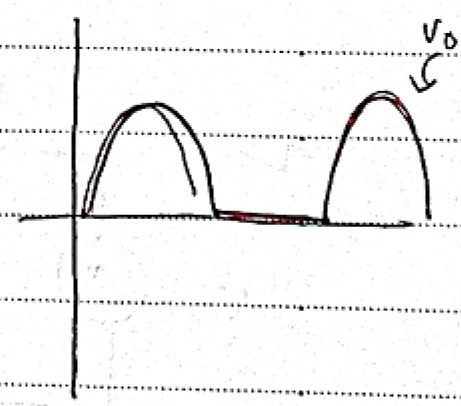




• Precision half-wave rectifier :-



not complete cct ⇐ Diode مستحيل يمر التيار عكس ال



• if $V_I > 0$ ⇒ $V_o > 0$ ⇒ $i_L \downarrow$ (Down) ⇒ . Diod is ON

. buffer cct

∴ $\boxed{V_o = V_I}$

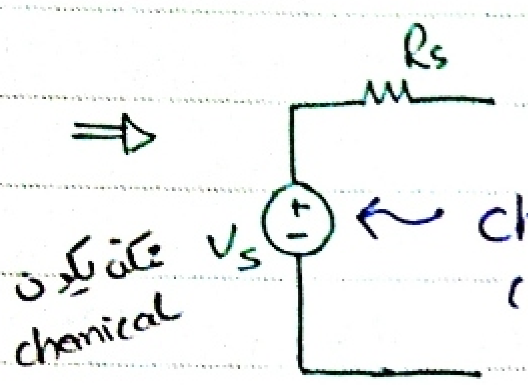
• if $V_I < 0$ ⇒ $V_o < 0$ ⇒ $i_L \uparrow$ (up) ⇒ . Diode is off

. it is not a complete cct

∴ $\boxed{V_o = 0}$

15/5/2014

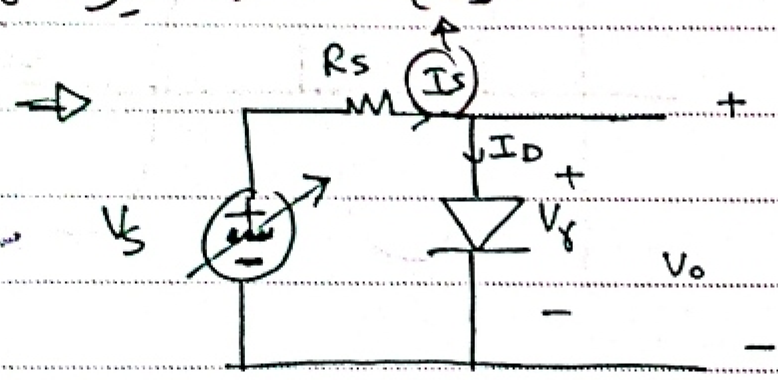
* Refrence voltage source design:-

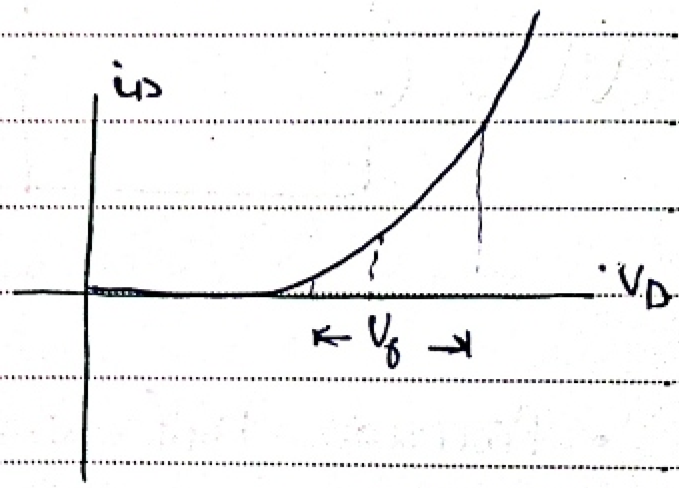


⇒ ← changable, and have R_s (with time)

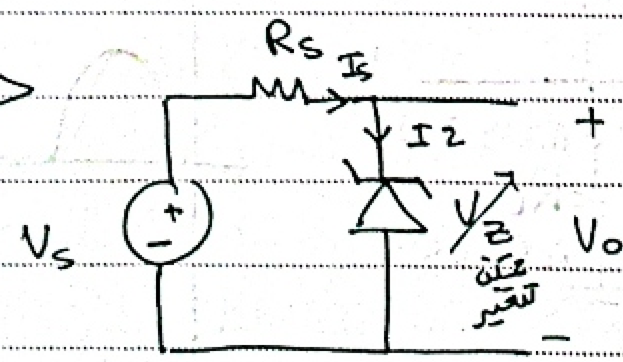
V_0 تتغير ⇐ I_D تتغير ⇐ V_s تتغير مع

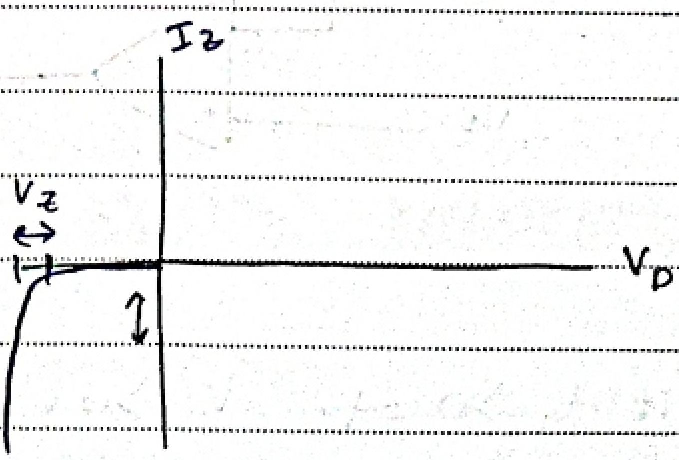
⇒





⇒





* problems:- ① V_Z changes with V_s
② in some cases we need a refrence voltage $\neq V_Z$

$V_s < V_z \rightarrow i_z = 0$

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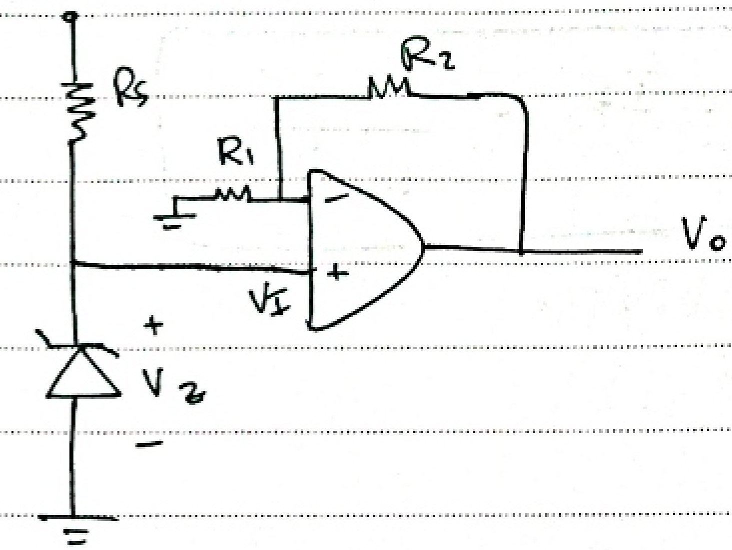
$V_s > V_z \rightarrow i \neq$ وبيكون V_z

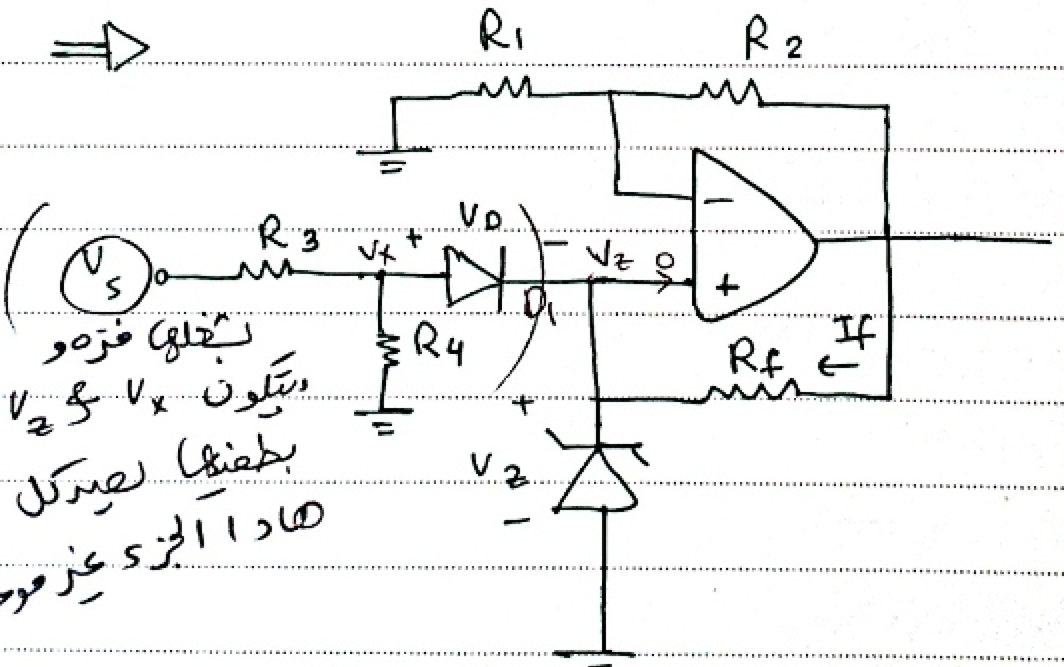
$\Rightarrow$



• if $V_s < V_z \Rightarrow V_I = V_s$

$V_s > V_z \Rightarrow V_I = V_z \rightarrow$ problem $\cancel{V_z}\nearrow$ as $\cancel{V_s}\nearrow$

$\Rightarrow$



بنخلي فرق و
وبيكون V_x & V_z
بطفيلي نعيد كل
هادا الجزء غير موجود.

" Refrence voltage source design "

D_1 is ON $\Rightarrow$ if $V_x - V_z > V_\gamma$

$$\Rightarrow V_o = V_z\left(1 + \frac{R_2}{R_1}\right)$$

$$I_f = \frac{V_o - V_z}{R_f} = \frac{R_2 V_z}{R_1 R_F}$$

$$\boxed{I_f = I_z = \frac{R_2 V_z}{R_1 R_F}}$$

18 / 5 /2014.

* feedback and stability:-

Type:- 1. Positive feedback
2. negative feedback ⊛

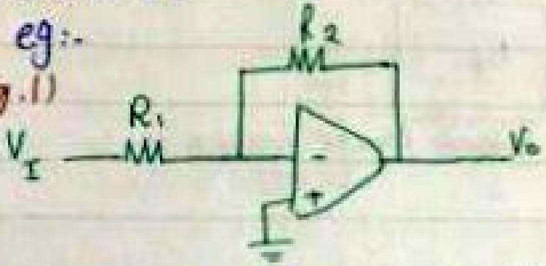
• negative feedback :-

Advantage:-

1. stable gain: the gain is independent on transistor parameter.

eg:-

(Fig.1)



$\text{Gain} = -\dfrac{R_2}{R_1}$

• gain without feedback = A_{od}

2. increases the bandwidth.

3. increases signal to noise ratio. $\left(\dfrac{S}{N}\right)\uparrow$ increase Good
signal power
noise power
لانه بيقلل ال noise

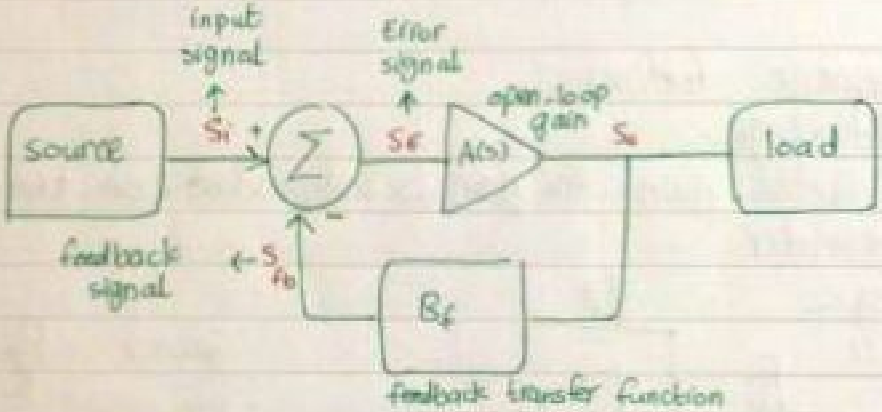
4. reduction of non-linear distortion.
↳ due to large signal. there's non-linear device or large signal to Amp

5. control of input and output impedance level

eg:- in (Fig 1) $R_i = R$.

- Disadvantages:-

1. reducing the gain.
2. the cct may become unstable (oscillate) at high frequencies.



$S_o = AS_E$

$S_{fb} = S_o B_f$

$S_E = S_i - S_{fb}$

$\therefore S_o = A(S_i - S_o B_f)$

$A_f = \dfrac{S_o}{S_i} = \dfrac{A}{1+BA}$ → the gain without feedback.

A_f → the gain with feedback

$$\boxed{A_f = \frac{A}{1+BA}}$$

- $A_f < A$ (Disadvantage)

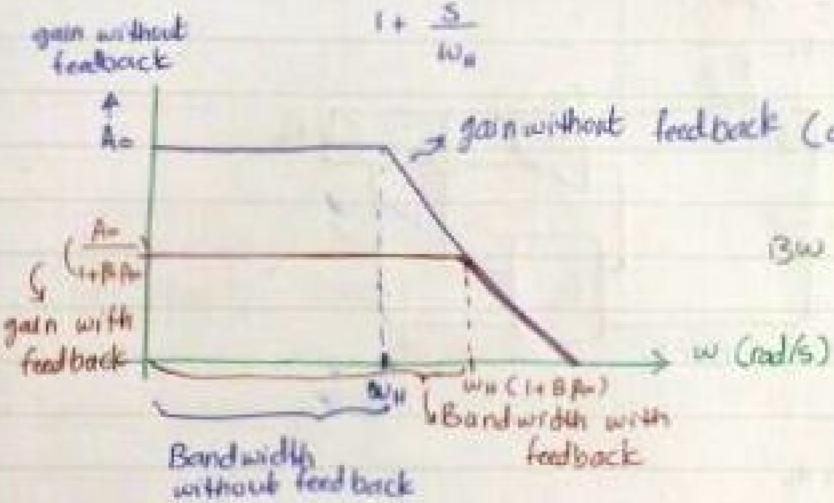
usually $BA \gg 1 \Rightarrow A_f = \dfrac{1}{B_f}$ → depends on feedback ↳ independent on op-amp parameter

⇓

Stable Gain.

* Bandwidth extension:-

let $A(s) = \dfrac{A_o}{1 + \dfrac{s}{\omega_H}}$



BW زاد , Gain قل

$$A_f(s) = \frac{A(s)}{1 + BA(s)}$$

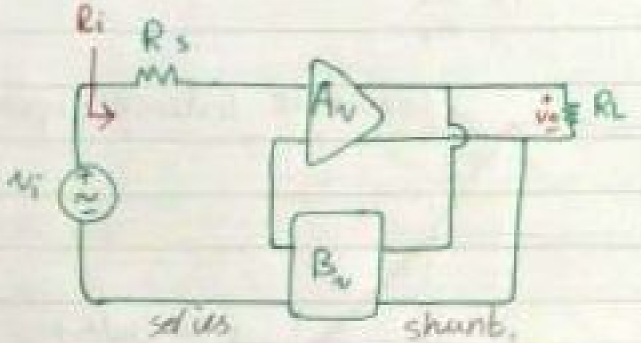
$$A_f(s) = \frac{A_o / (1 + \frac{s}{\omega_H})}{1 + BA_o / (1 + \frac{s}{\omega_H})}$$

$$A_f(s) = \frac{A_o}{1 + BA_o} \cdot \frac{1}{1 + \dfrac{s}{\omega_H(1 + BA_o)}}$$

- Gain ↓ × Bandwidth ↑ = constant

* Basic feedback configurations:-

(a) series _ shunt: (as parallel)



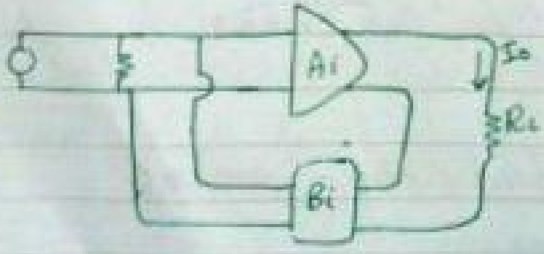
- $A_f = \dfrac{A_v}{1 + B_v A_v}$
- $R_{if} = R_i(1 + B_v A_v)$, R_{if}: R input with feedback
  R_i: R input without feedback
- $R_{of} = \dfrac{R_o}{1 + B_v A_v}$

* بالمقارنة $R_i \leftarrow$ تزداد % في الضرب ب $(1+B_vA_v)$

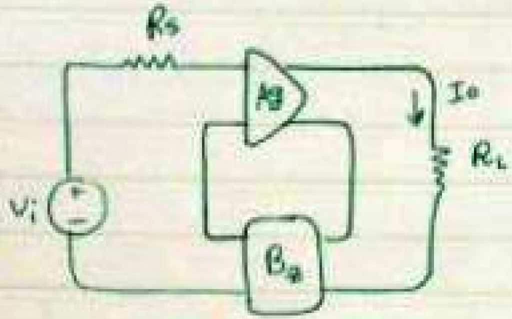
$R_o \leftarrow$ تقل

$A \leftarrow$ يقل

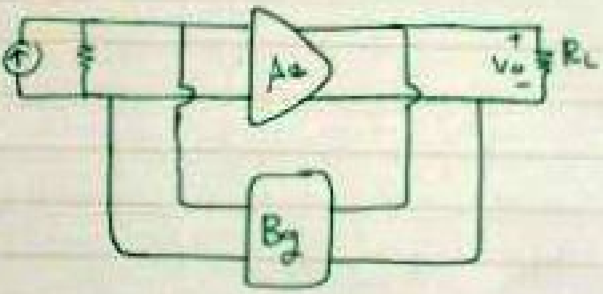
(b) shunt - series:



(c) series - series:-



(d) shunt - shunt:



• Miller effect of Mosfet → $C_M = ?$ بطلع