# Amplifiers

## Revision

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POWER UNIT

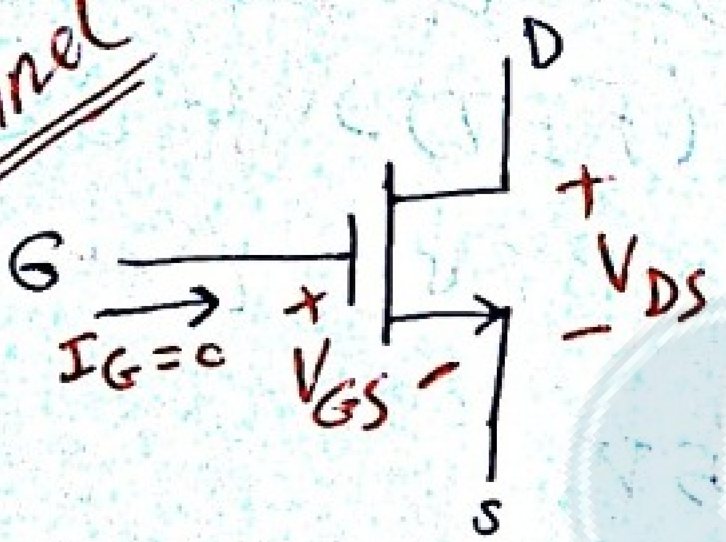
ELECTRICAL ENGINEERING

* FET ⇒ field effect Transistor.

| FET | | BJT |
|---|---|---|
| G | ⟶ | B |
| D | ⟶ | C |
| S | ⟶ | E |

## FET

N-channel




→ control by $V_{GS}$ « Voltage »

→ Work as Amp. In saturation mode

→ condition of sat. mode in FET.

$$V_{DS_Q} > V_{DS_{sat}}$$

→ $V_{DS_{sat}} = (V_{GSQ} - V_{TN})$

$V_{TN}$ ⇒ constant → given

→ $I_D = K_n (V_{GSQ} - V_{TN})^2$

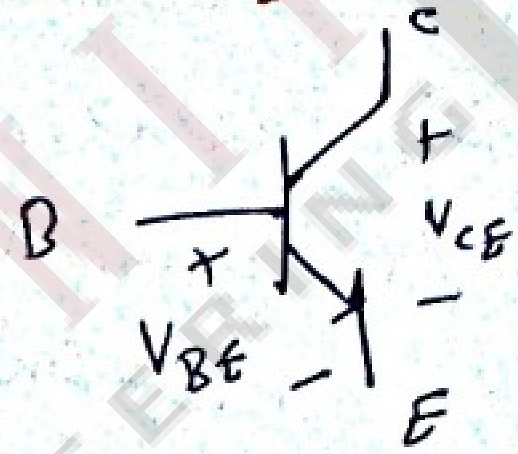
→ $g_m = 2K_n (V_{GSQ} - V_{TN}) = \dfrac{dI_d}{dV_{GSQ}}$

→ $r_\pi = \infty$ ≡ open circuit

→ $r_o = [\lambda I_D]^{-1} = 1/\lambda I_D$

## BJT

NPN




→ control by $I_B$ « current »

→ work as Amp. In F.W mode

→ condition of F.W mode

$$V_{CE_Q} > V_{CE_{sat}}.$$

→ $V_{CE_{sat}} = 0{,}2$ or $= 0{,}3$

→ $I_C = \beta I_B$

→ $g_m = \dfrac{I_{CQ}}{V_T = 0{,}026}$

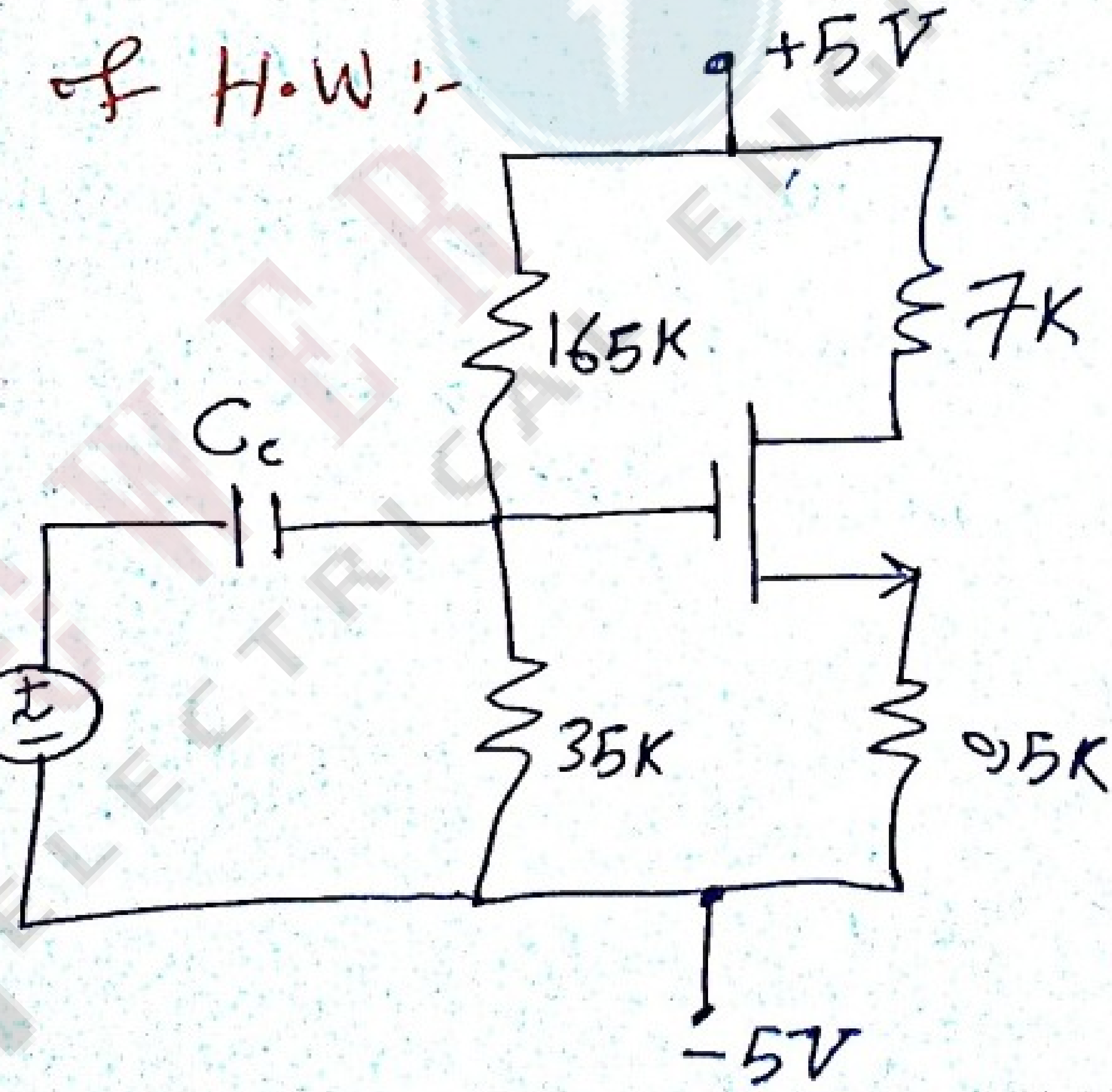
→ $r_\pi = \dfrac{0{,}026}{I_B}$

→ $r_o = \dfrac{0{,}026}{I_C}$

| FET | BJT |
|---|---|
| $I_G = 0$ | $I_E = I_C + I_B$ |
| $I_S = I_D = K_n(V_{GSQ} - V_{TN})^2$ | $= \beta I_B + I_B$ |
| $K_n$ :- constant → given | ~~$= I_B(\beta + \beta)$~~ |
| | $= I_B(\beta + 1)$ |
| → $A_V$ = Low because $g_m$ is Low | → $A_V$ = High because $g_m$ High |

⇐ بعد ما نحفظ هذه القوانين بعدين بنصير بنطبق ونشتغل على ال (FET) زي ما كنا نشتغل على ال (BJT). بالربط بعمج مراعاة هذه القوانين السابقة.

solution of H.W :-

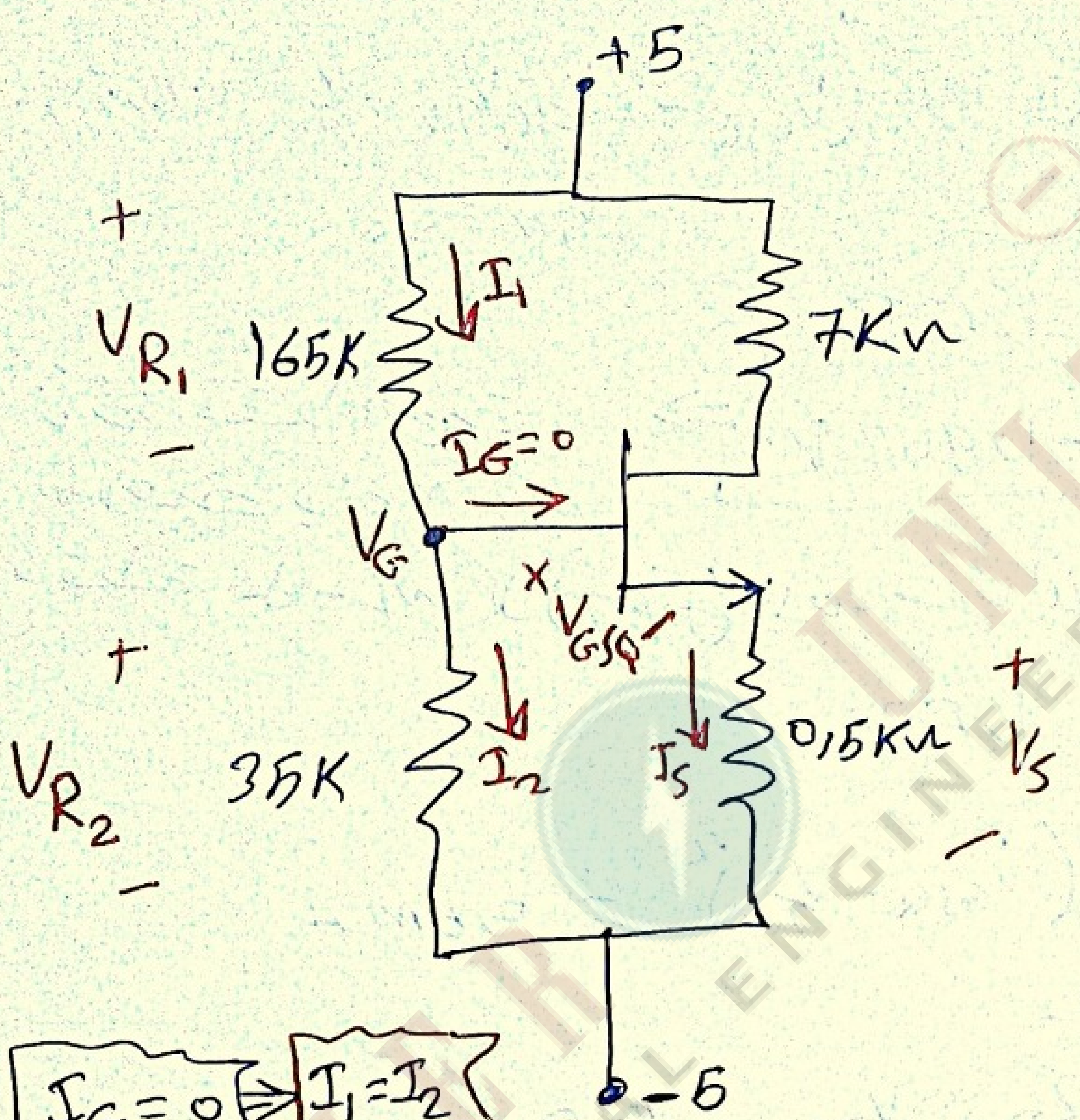



Let $V_{TN} = 0.8V$ , $K_n = 1 mA/V^2$ , $\lambda = 0 V^{-1}$

find $A_V$ and Draw Dc Load Line

...ution:-

→ Dc Analysis:-




$\boxed{I_G=0} \Rightarrow \boxed{I_1=I_2}$

$$V_{R_2} = 10 \times \frac{35K\Omega}{35K\Omega + 165K\Omega} = 1,75$$

⇐ هون أنا اعملها ~~...~~ (Voltage Division) مشان

$\boxed{I_G=0} \Rightarrow \boxed{I_1=I_2}$ تفصيل كادر بعد أكمل Voltage Div.

⇒ at input Loop:-

KVL:- ~~$V_{R_2}$~~ $-V_{R_2} + V_{GSQ} + V_S = 0$

$$\Rightarrow -1,75 + V_{GSQ} + I_S\,(0,5 \times 10^{3}) = 0$$

but $I_S = I_D = K_n\,(V_{GSQ} - V_{TN})^2$.

$\Rightarrow -1{,}75 + V_{GSQ} + K_n[V_{GSQ} - V_{TN}]^2 \times (0{,}5\,K\Omega) = 0$

$\Rightarrow -1{,}75 + V_{GSQ} + 1\times 10^{-3}(V_{GSQ}^2 - 2V_{GSQ}V_{TN} + V_{TN}^2) \times 0{,}5 \times 10^{3} = 0$

$V_{TN} = 0{,}8$

$\Rightarrow \boxed{\begin{array}{l} V_{GSQ} = 1{,}5\,V \\ V_{GSQ} = -1{,}903\,V \end{array}} \Rightarrow$ ناخذ فقط القيمة الموجبة لانه لا يوجد نقطة عمل سالبة للـ(FET) لانه سوف لا يكون في (sat.).

$\Rightarrow V_{GSQ} = 1{,}5\,V$

$\Rightarrow I_{DQ} = K_n(V_{GSQ} - V_{TN})^2 = 0{,}5\,mA$

at out Loop :-

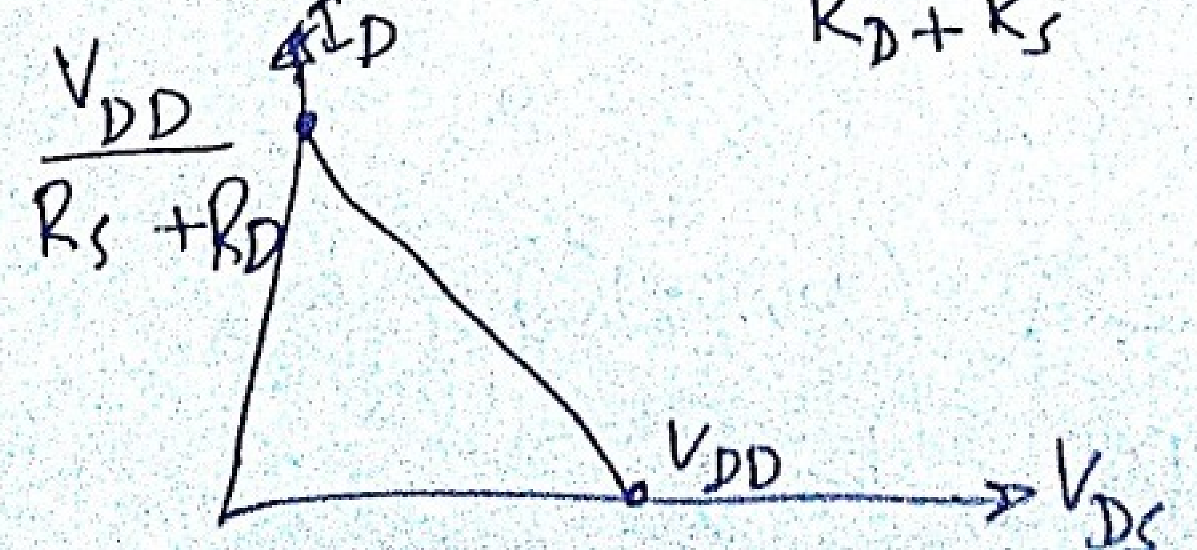
$-5 + I_{DQ}R_D + V_{DSQ} + I_S R_S - 5 = 0$

$\rightarrow \Rightarrow V_{DSQ} = 6{,}25\,V$

$\Rightarrow$ DC Load Line

$-V_{DD} + I_D R_D + V_{DS} + I_S R_S = 0$ but $\boxed{I_S = I_D}$

$$\Rightarrow I_D = -\frac{V_{DS}}{R_D + R_S} + \frac{V_{DD}}{R_D + R_S}$$

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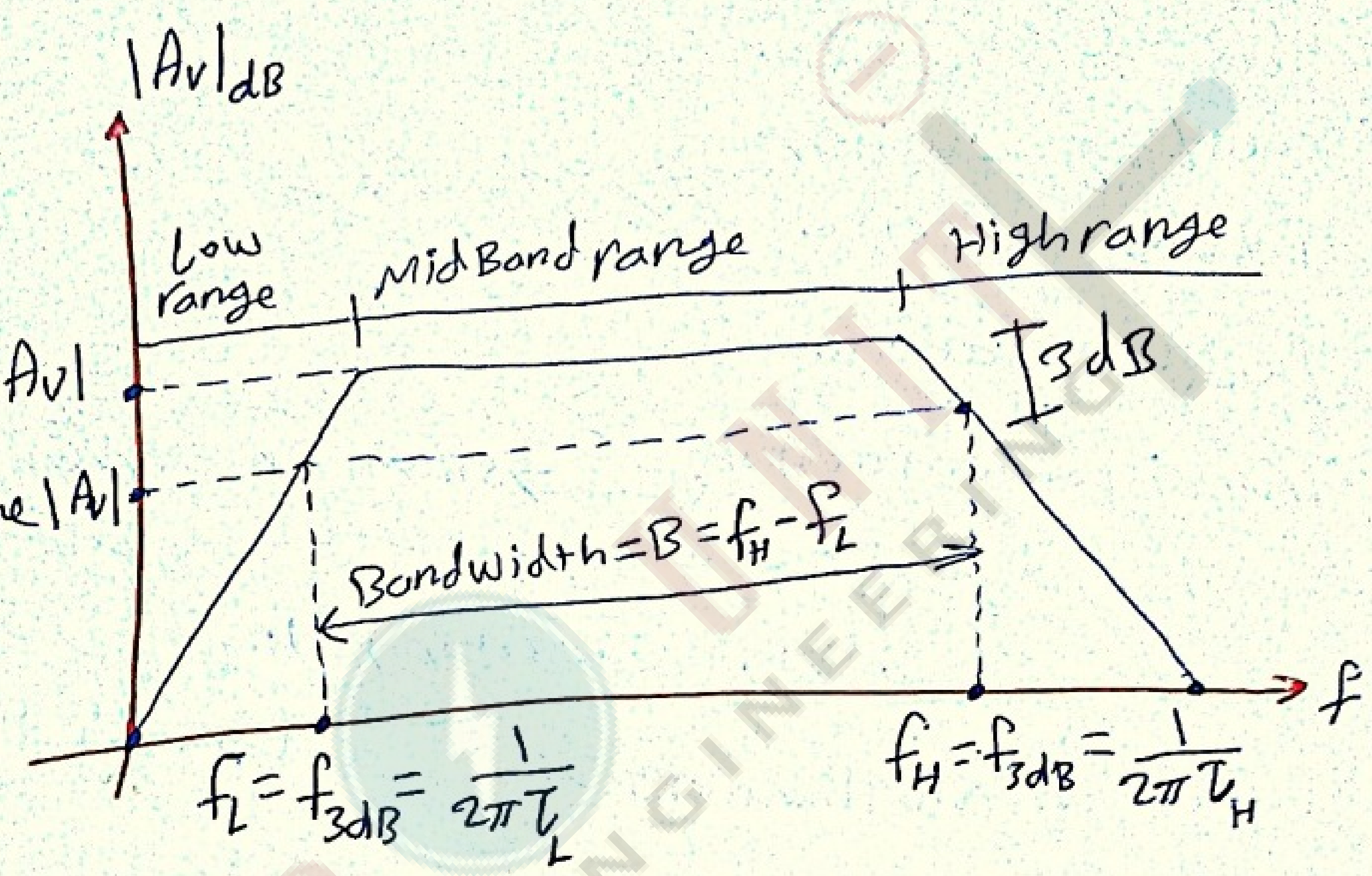
o Frequancy Response :-

It's the study-state output of a linear system due to a sinusoidal input.

→ In general Amplifier circuit has :-




* هلا أنا هون راح أشرح بطريقة مختلفة شوي عن الكتاب ومختلفة شوي عن ترتيب الدكتور.

← وحدة ال $A_V$ بشكل عام هي ال (unitless)

$$A_V = \frac{V_o}{V_{in}} \text{ unitless}$$

← هناك وحدة أخرى لل ($A_V$) وهي ال (dB)

← وللتحويل من ال (unitless) لل (dB) راح نستخدم هذي العلاقة

$$\boxed{dB = 20 \log_{10} (\text{unitless})}$$

$$\Rightarrow \boxed{\text{unitless} = (10)^{dB/20}}$$

هلا الهدف الرئيسي انو كيف بدنا نوجد ($\tau$) عشان
انطلع منها ال $(f_{3dB}) \Leftarrow \left( f_{3dB} = \frac{1}{2\pi\tau} \right)$

* Type of capacitor are

① coupling capacitor
② Bybass capacitor $\Rightarrow$ group#1 $\equiv G_1$

③ Load capacitor
④ Transistor capacitor $\Rightarrow$ group#2 $\equiv G_2$ $\rightarrow$ shown In Higher freq.

* هلا بالامتحان رح بأي سؤال راح نطلع على قيم ال (capacitor) وبنشوف كيف وضع ال (capacitor) راح يكون، وكيف بتغير مع تغير ال (freq.).

~~open circuit / short circuit~~

$\Leftarrow$ حالات ال (capacitor) بتغير ال (freq.)
① $\leftarrow$ open circuit
② $\leftarrow$ short circuit
③ $\leftarrow$ No-chang $\Rightarrow$ ((Have Value))

$$Z_C = \frac{1}{j2\pi \underline{\underline{f}}\, \underline{\underline{C}}}$$

* على سبيل المثال:

In Practical case group#1 $\gg$ group#2

بهاي الحالة رح نشوف كيف ال (capacitor) راح يكون في كل حالة من حالات ال (freq).
ورح نعتمد على هذا القانون

$$\boxed{Z_C = \frac{1}{j2\pi \underline{\underline{f}}\, \underline{\underline{C}}}}$$

group*1 >> group*2 ⇐ Practical cases

| freq. cases | group*1 of (C) | group*2 of (C) |
|---|---|---|
| at Low freq<br>منها الي بطلعة بجيب ال ($f_L$)<br>$\Rightarrow f_L = \frac{1}{2\pi \tau_L} = f_{3dB}$ | $Z_c = \frac{1}{j2\pi f C}$ $f\downarrow$ $C\uparrow$<br>$f$ is Low but $C$ is High<br>$\Rightarrow Z_c$ = Have Value<br>$\Rightarrow C \equiv$ No change | $Z_c = \frac{1}{j2\pi f C}$ $f\downarrow$ $C\downarrow$<br>$f$ is Low and $C$ is Low<br>$\Rightarrow Z_c \approx \frac{1}{0} = \infty$<br>$\Rightarrow C$ = open circuit |
| at MidBand freq.<br>فيها أشياء كثير منستفيد في مادة ال (First) وأهمها منها الي بطلعة بجيب ال $A_V$. | $Z_c = \frac{1}{j2\pi f C}$ $C\uparrow$<br>$f$ is constant but ~~C is Hig~~<br>$C$ is High<br>$\Rightarrow Z_c = \frac{1}{\infty} = 0$<br>$\Rightarrow C \equiv$ short circuit | $Z_c = \frac{1}{j2\pi f C}$ $C\downarrow$<br>$Z_c = \frac{1}{0} = \infty$<br>$\Rightarrow C \equiv$ open circuit |
| at High freq.<br>منها الي بطلعة بجيب ال ($f_H$)<br>$f_H = \frac{1}{2\pi \tau_H}$ | $Z_c = \frac{1}{2\pi f C}$ $f\uparrow$ $C\uparrow$<br>$f$ is High and $C$ is High<br>$\Rightarrow Z_c = \frac{1}{\infty} = 0$<br>$\Rightarrow C \equiv$ short circuit | $Z_c = \frac{1}{2\pi f C}$ $f\uparrow$ $C\downarrow$<br>$f$ is High but $C$ is Low<br>$\Rightarrow Z_c$ = Have Value<br>$\Rightarrow C \equiv$ No change. |
| at DC range<br>$\Rightarrow f = 0$ | $Z_c = \frac{1}{0} = \infty$<br>$C \equiv$ open circuit | $Z_c = \frac{1}{0} = \infty$<br>$\Rightarrow C \equiv$ open circuit |

* بس تذكر إنو بالامتحان مش شرط يجيبيلنا هذي الحالة إنه (group*1 >> *2) فلازم أنا انتبه على قيم ال (C) المعطاه وأشوف من العتبر ال (High) ومين العتبر ال (Low) وبعمل مقارنة زي مثل شوي.

زي ما حكينا قبل شوي ، الهدف من ال op (freq. responce)

إني أجيب ال ($\tau$) ومنها بوجد ال ($f_{3dB}$) .

⇒ How I can find $\tau$ ??

→ ① find ($\tau$) by the curve

or → ② find ($\tau$) by the Transfer function

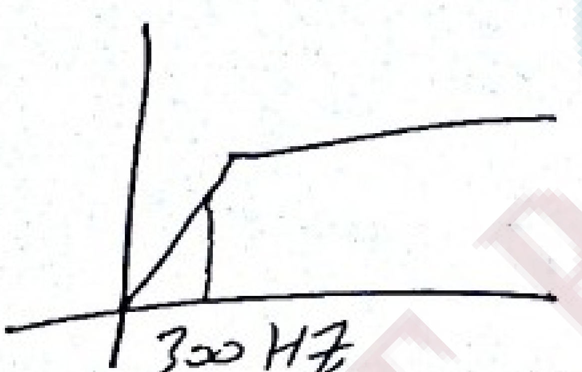
or → ③ find ($\tau$) by the given circuit.

Now :-

① find ($\tau$) from the curve :- $\rightarrow \tau = \frac{1}{2\pi f}$

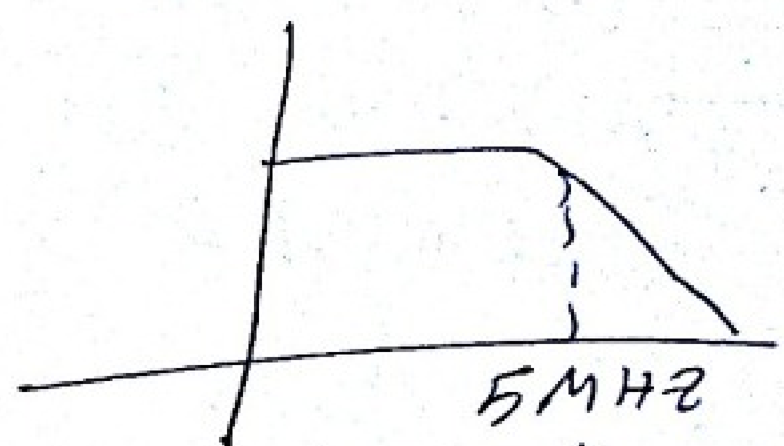
Ex :-

①



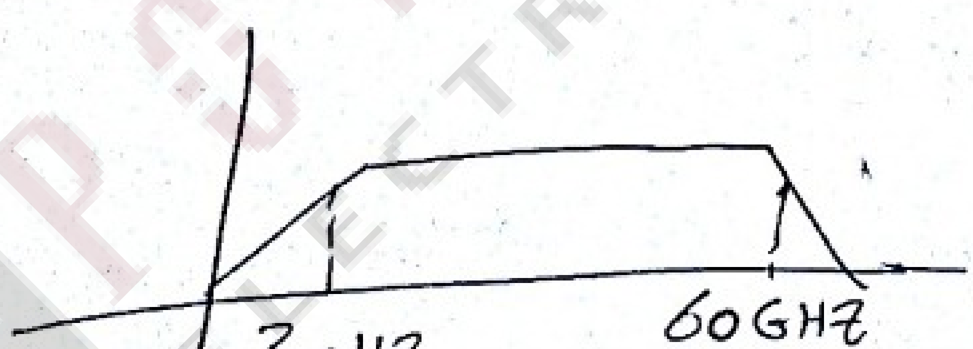

$\hookrightarrow \tau = \frac{1}{2\pi f} = \frac{1}{2\pi \times 300}$ sec

②




$\hookrightarrow \tau = \frac{1}{2\pi \times 5 \times 10^6}$ sec

③




$\Rightarrow \tau_1 = \frac{1}{2\pi \times 300}$ sec

$\tau_2 = \frac{1}{2\pi \times 60 \times 10^9}$ sec.

2. Find ($\tau$) from the circuit.

$\Rightarrow$ We Have Two cases :-

1- if I have 1 capacitor in my circuit

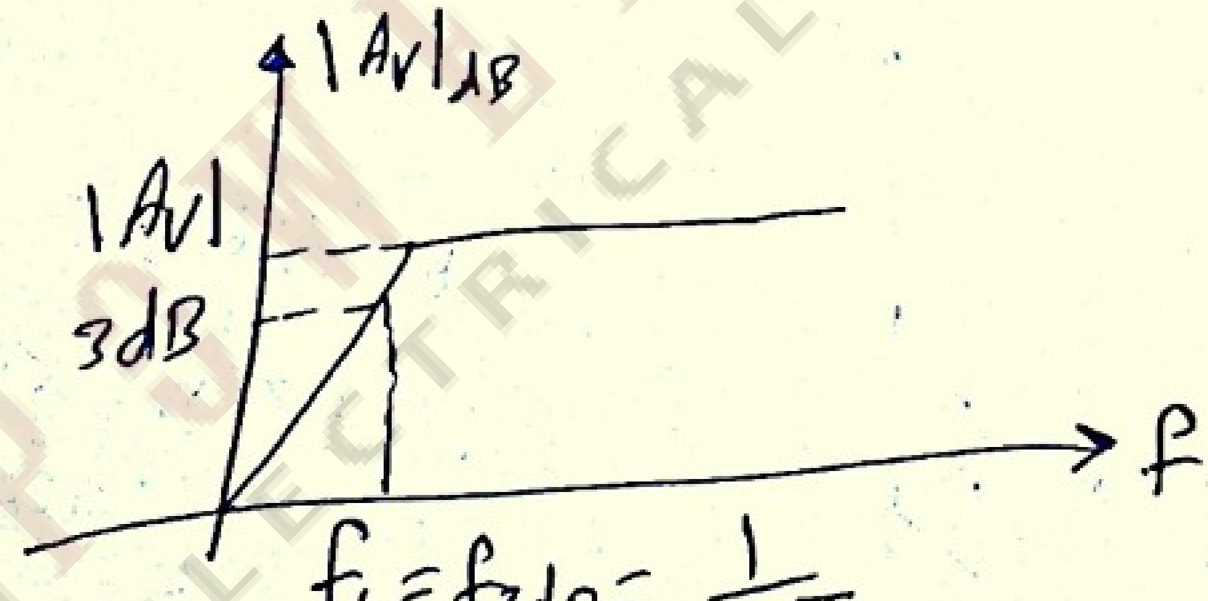
2- If I have 2 capacitor " " "

$\rightarrow$ 1 capacitor in my ~~circuit~~ circuit :-

$$\tau = R_{eq} \times C \quad ; \quad \boxed{R_{eq} = R_{th}}$$

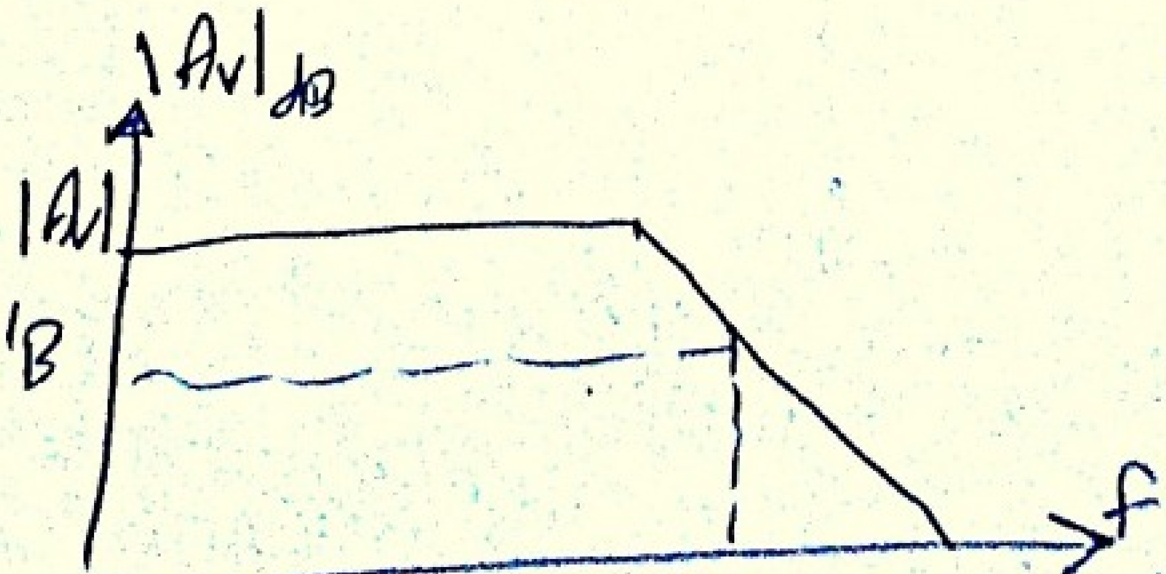
$$\Rightarrow \boxed{\tau = R_{eq} \times C = R_{th} C}$$

$\Rightarrow$ frequancy response :-



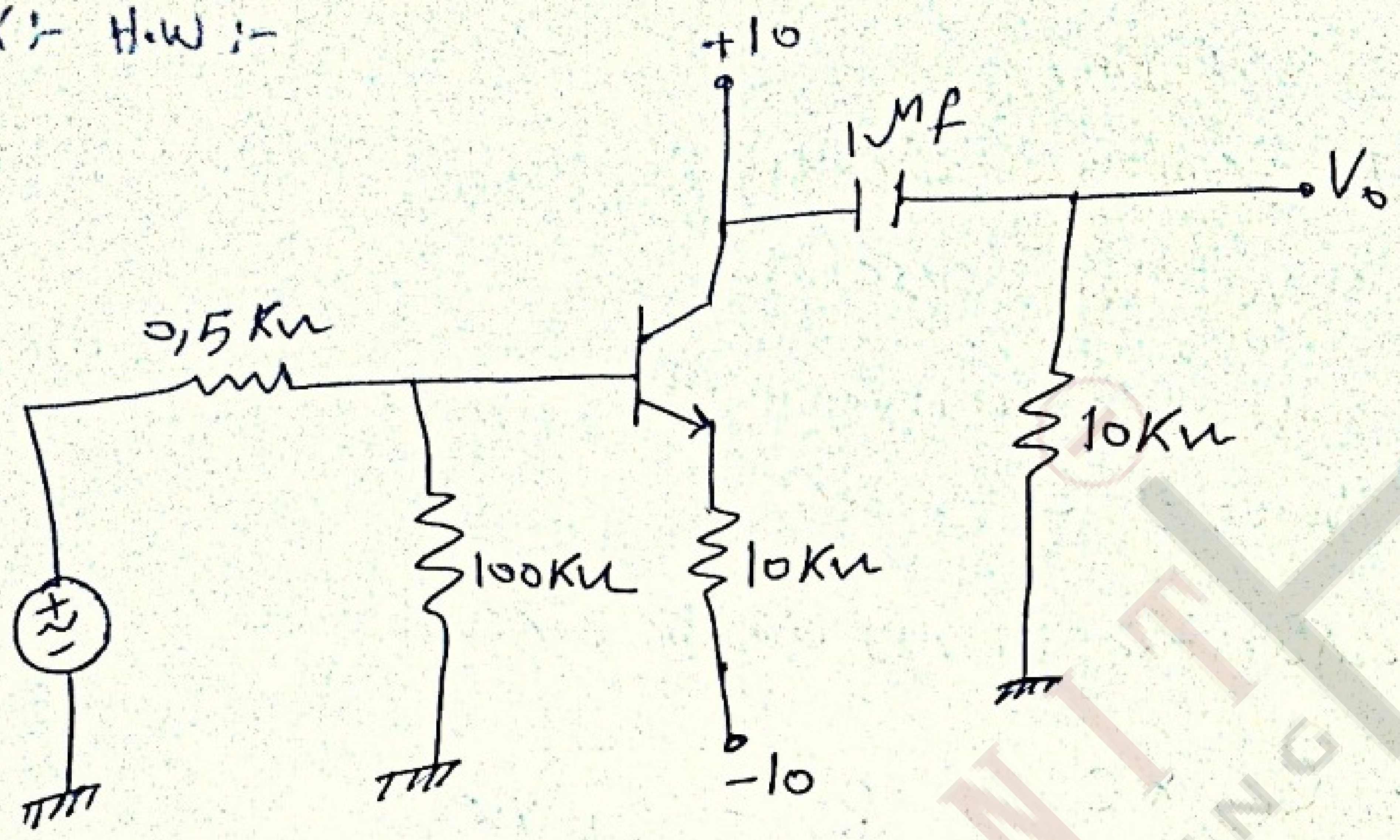

$f_L = f_{3dB} = \frac{1}{2\pi \tau_L}$

$\boxed{I_B}$




$f_H = f_{3dB} = \frac{1}{2\pi \tau_L}$

EX:- H.W :-

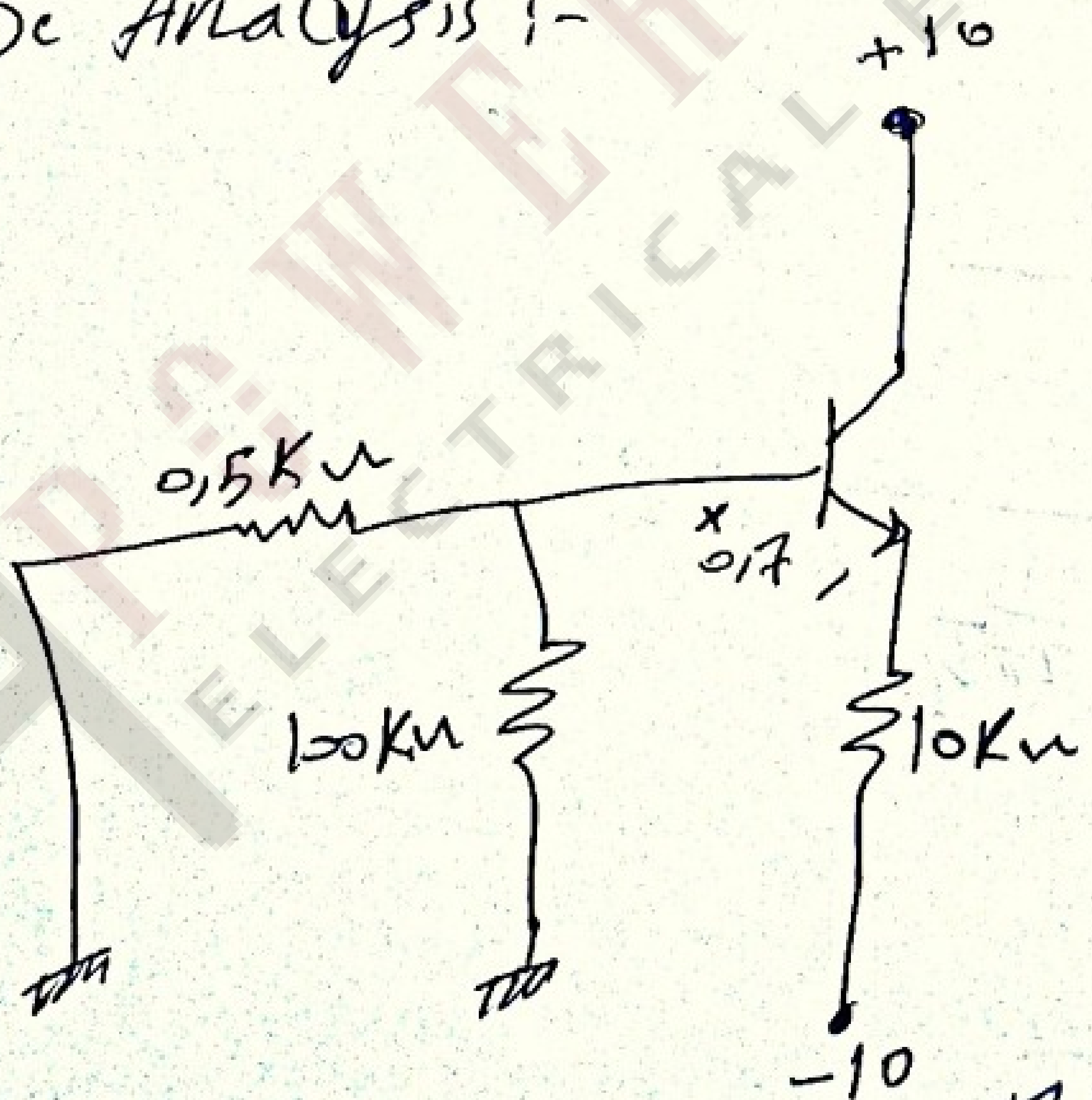



find $\tau$ and $f_{3dB}$.

$\beta = 100$ , $V_{BE_{on}} = 0,7$ , $V_A = 120$ .

Solution:-

⟶ Dc Analysis :-




$R_s \parallel R_B =$

$= \boxed{100 \parallel 0,5 K\Omega}$

$= \boxed{497,5 \Omega}$

$0,7 + I_E(10\times10^3) - 10 + I_B (497,5) = 0$ ; $\boxed{I_E = (1+\beta) I_B}$

$\Rightarrow 0,7 + I_B(101)(10\times10^3) - 10 + I_B (497,5) = 0$

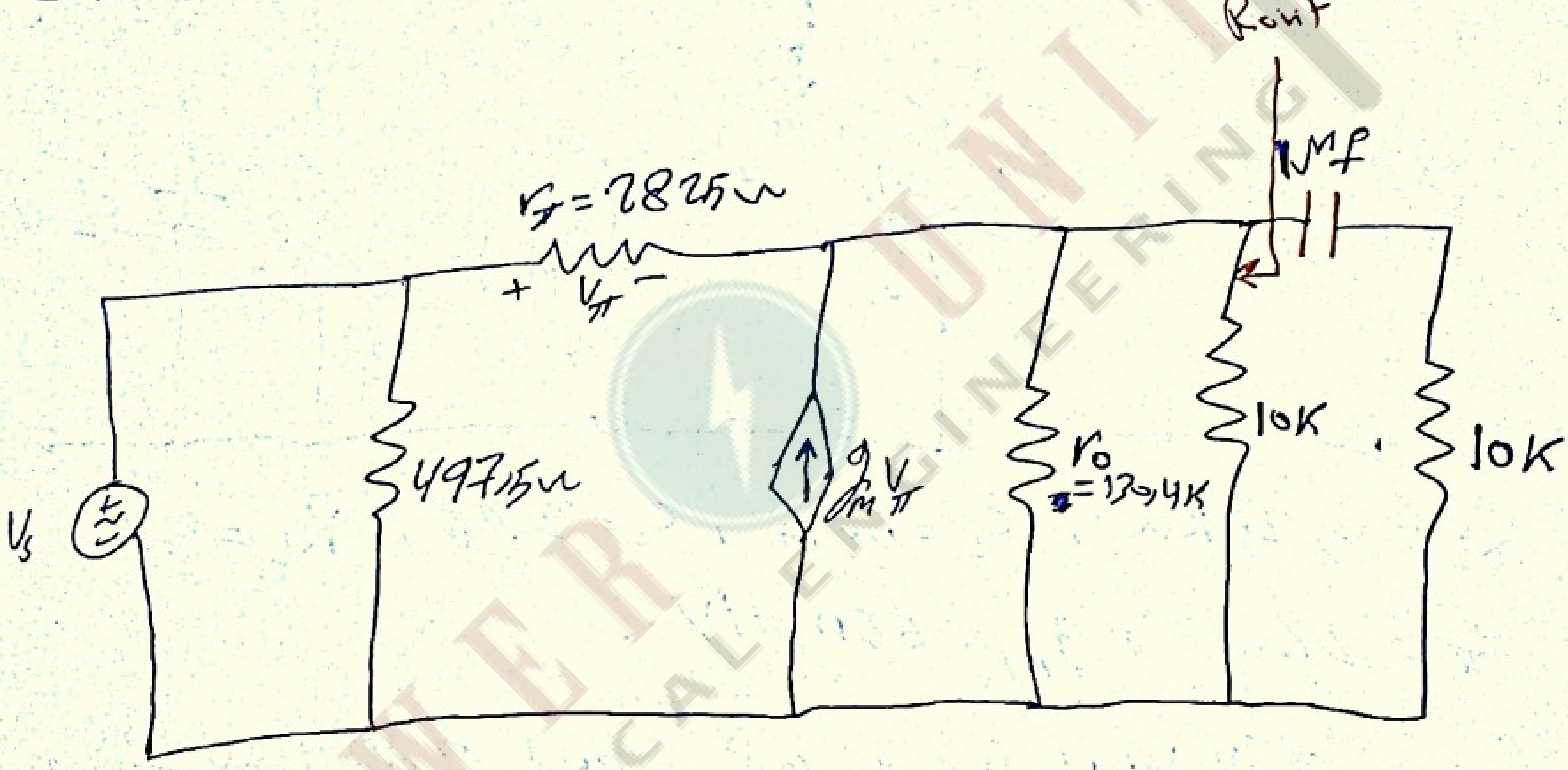
$\Rightarrow \boxed{I_B = 9,2 \mu A} \Rightarrow \boxed{I_C = \beta I_B = 9,2\times10^{-4} A}$

$$\Rightarrow r_\pi = \frac{0{,}026}{I_B} = 2825\ \Omega$$

$$r_o = \frac{V_A}{I_C} = 130{,}435\ K\Omega$$

$$g_m = \frac{I_C}{0{,}026} = 0{,}0354\ \mho$$

→ Ac circuit :-




$$\tau = R_{th} * C \quad ; \quad R_{th} = R_{out} + R_L$$

→ This circuit is C.C Amplifier

$$\Rightarrow R_{out} = R_E \parallel r_o \parallel \left[ \frac{r_\pi + (R_S \parallel R_B)}{1+\beta} \right] = 32{,}8\ \Omega$$

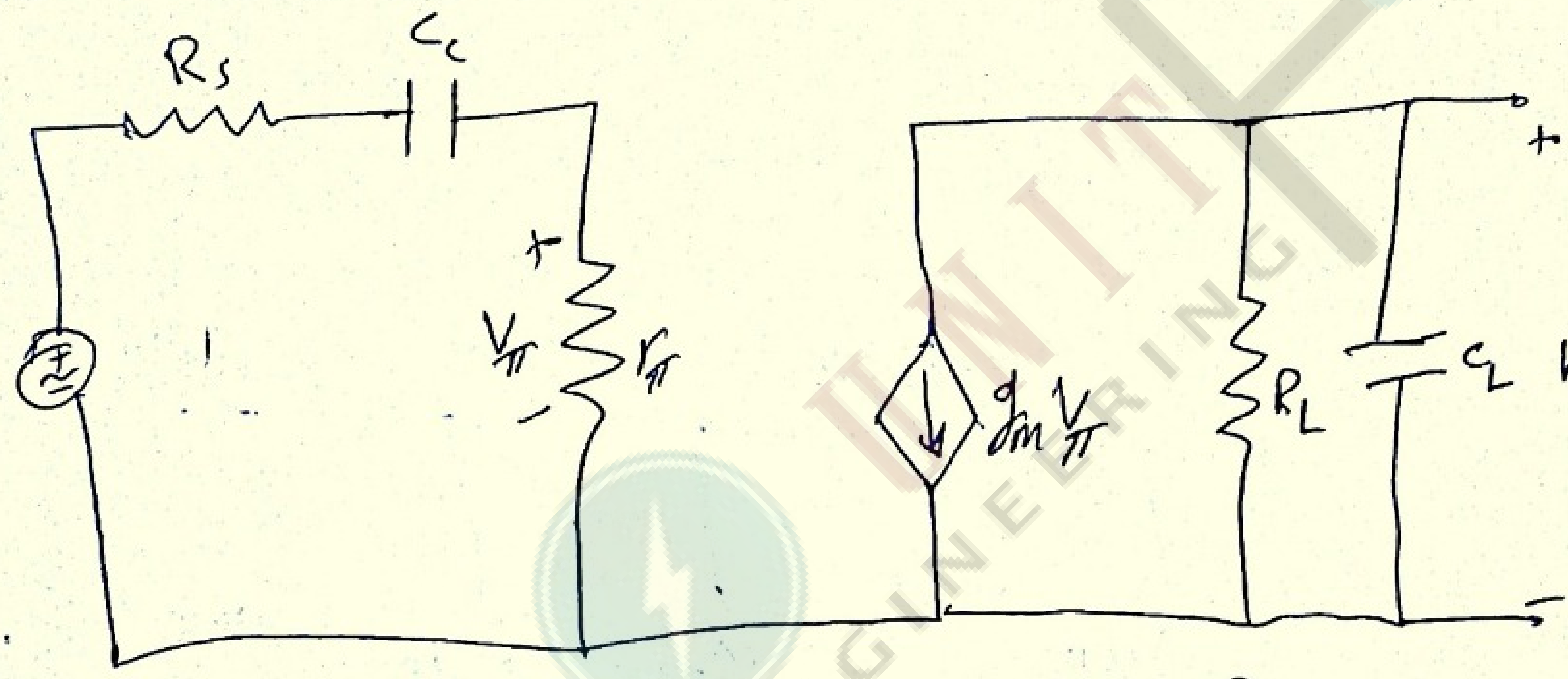
$$\Rightarrow R_{th} = 10032{,}8\ \Omega$$

$$\Rightarrow \tau \cong 0{,}01\ sec \Rightarrow f_{3dB} = f_L \cong 15{,}9\ HZ$$

→ case 2 → 2 capacitor :-

→ So we will use open circuit test and short circuit test.

Ex :-




$R_s = 0,25K\Omega$ , $C_L = 50pf$ , $C_c = 2\mu f$ , $R_L = 4K$

$r_\pi = 2K\Omega$ , $g_m = 65mA/V$ .

find 3dB High freq. « $f_H$ » and 3dB Low freq. « $f_L$ ». and find $A_V$

solution :- $C_c \gg C_L$

→ at Low freq.

$$\Rightarrow Z_c = \frac{1}{2\pi \underset{\downarrow}{f} \underset{\uparrow}{C_c}} = \text{Have Value}$$

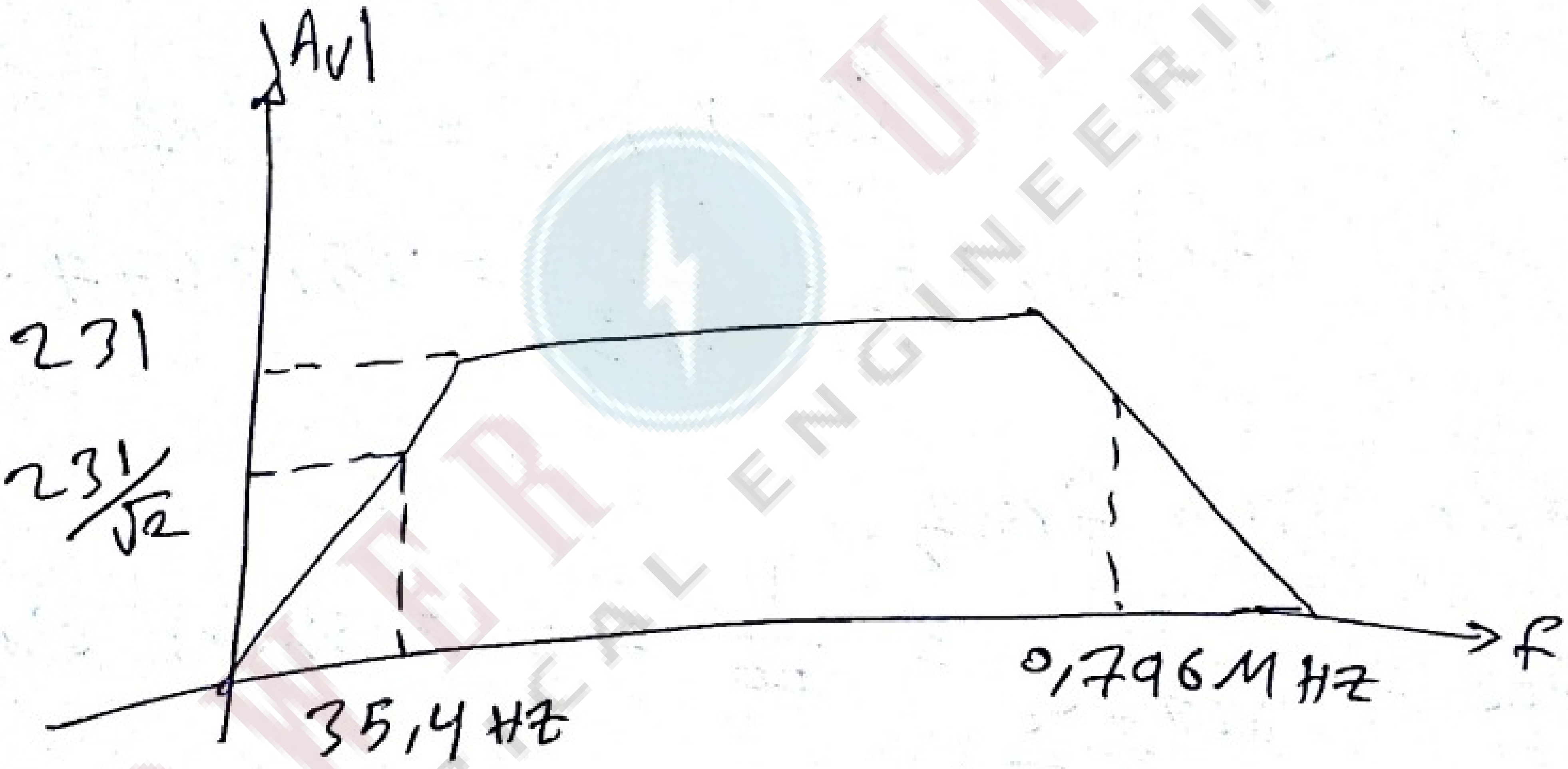
$$Z_L = \frac{1}{2\pi \underset{\downarrow}{f} \underset{\downarrow}{C_L}} = \frac{1}{0} = \infty = \text{open circuit}$$

$f_{3dB} = f_H = \frac{1}{2\pi \tau_H} = 0,796 \ MHz$

→ at Mid Band Range to find $A_v$ :-

$Z_{cc}$ = short circuit , $Z_{CL}$ = open circuit

$$A_v = -g_m \frac{R_L \, r_\pi}{r_\pi + R_s} = -231 \Rightarrow |A_v| = 231$$



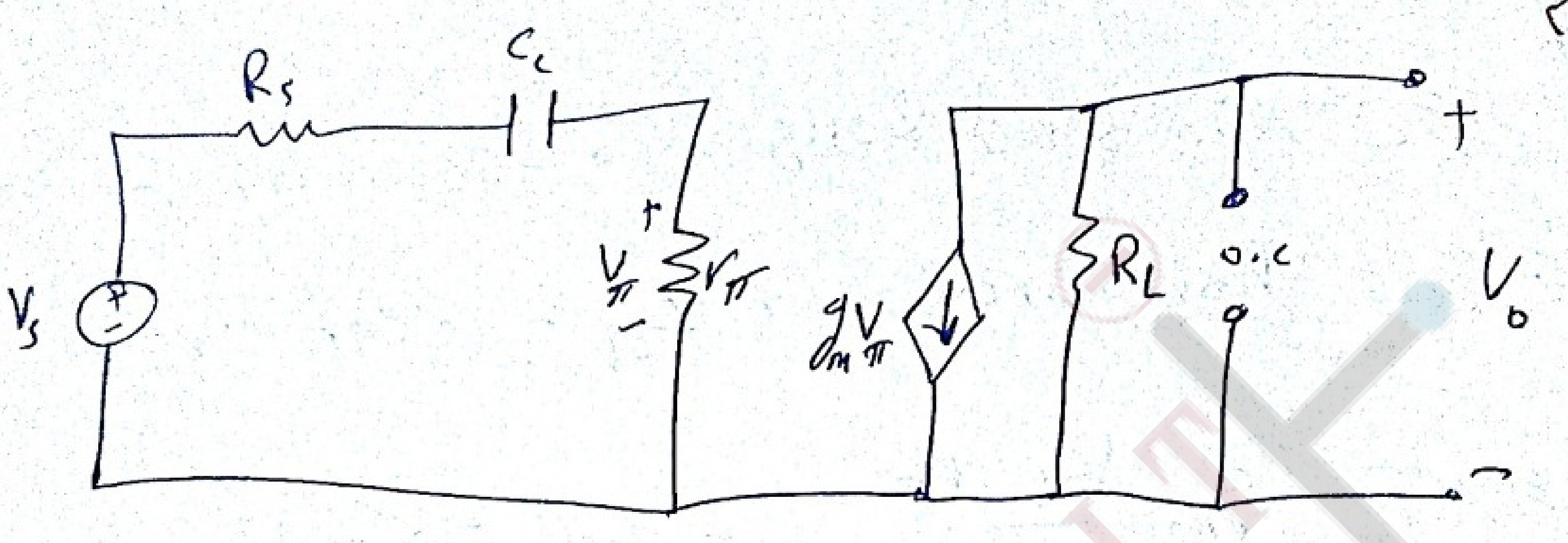

[3] How I can find ($\tau$) from Transfer function T(s)

Transfer function T(s) :-

$S = jw = j2\pi f$ :- complex frequancy.

$$Z_c = \frac{1}{j2\pi f c} = \frac{1}{jwc} = \frac{1}{Sc} \ \Omega.$$

⇒ Draw the New circuit at Low freq.




⇐ أصبحت ال (circuit) تحتوي على (1 capacitor)

$$\Rightarrow \tau = R_{th} C_c = (R_s + r_\pi) C_c = 4.5 \mu f$$

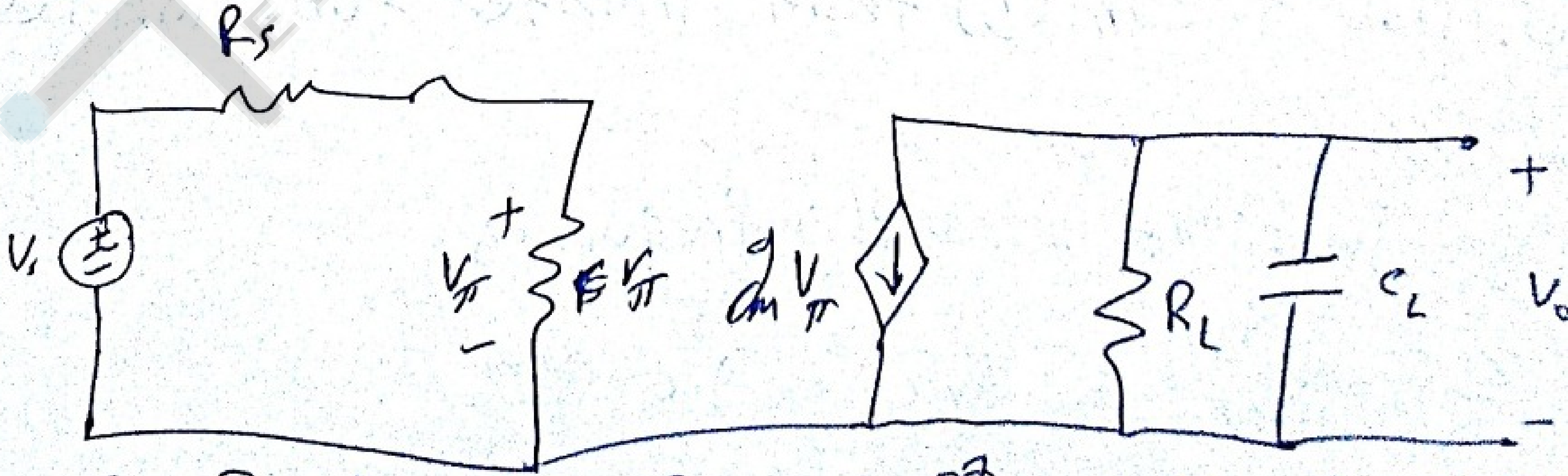
$$\Rightarrow f_{3dB} = f_L = \frac{1}{2\pi \tau_L} = 35.3677 \, HZ$$

⇝ at High freq.

$$Z_{cc} = \frac{1}{j2\pi \underset{\uparrow}{f} \underset{\uparrow}{C_c}} = \frac{1}{\infty} = 0 \equiv \text{short circuit}$$

$$Z_{C_L} = \frac{1}{2\pi f C_L} = \text{Have Value}$$

⇒ Draw the New circuit at High freq.




$$\tau = R_{th} C_L = C_L \times R_L = 2 \times 10^{-7} \, sec$$

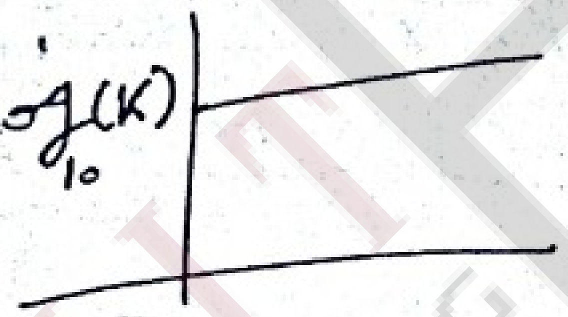
How I can Draw The frequancy responce??

→ BY Bode Plot :-

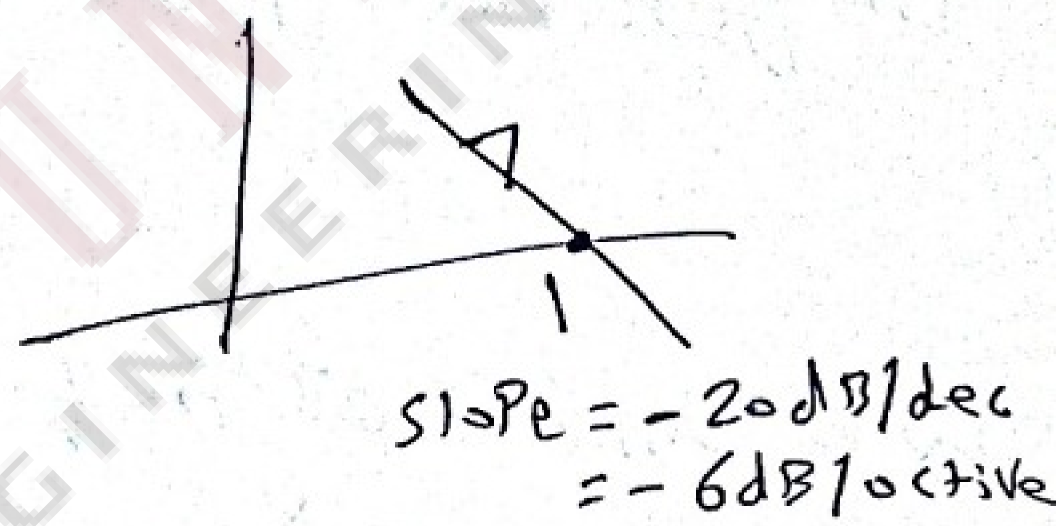
* Bode Plot :-

يجب علينا حفظ الصيغ ال (5) التالية , حفظ الأشكال.

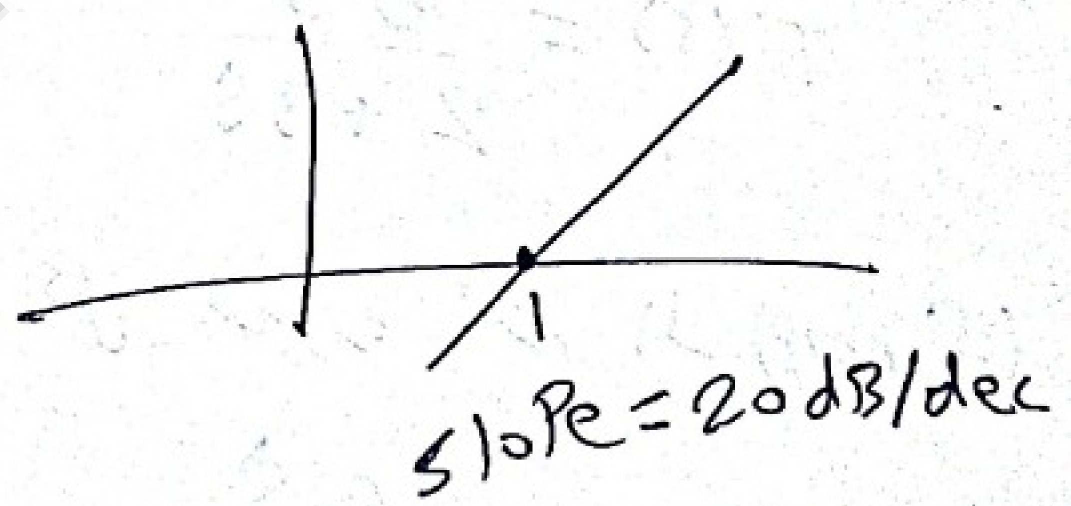
[1] $G(jw) = G(S) = K \Rightarrow$



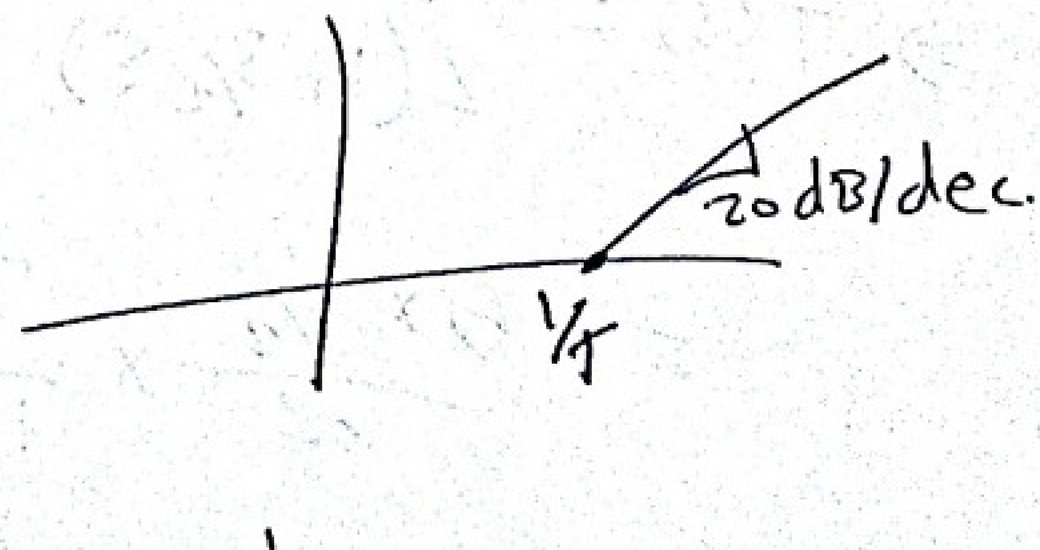

[2] $G(S) = \frac{1}{S}$



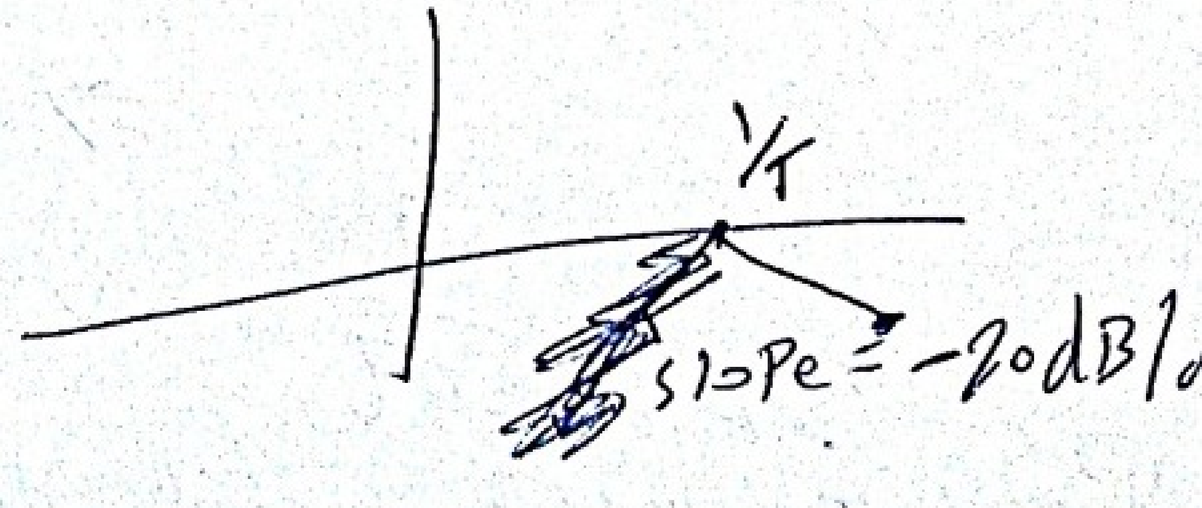

[3] $G(S) = S \Rightarrow$




[4] $G(S) = 1 + ST$ ; $T \equiv$ const. $\Rightarrow$




[5] $G(S) = \frac{1}{1+ST} \Rightarrow$




* راجع المثال الموجود بالدفتر *

→ In Amplifier cource we will consider two Ti...

Type « forms » of $T(s)$ :-

$$\boxed{T_1(s) = K_1 \times \frac{1}{1+s\tau_1}}$$

$$\boxed{T_2(s) = K_2 \times \frac{s\tau_2}{1+s\tau_2}}$$

In general $\boxed{T(s) = \frac{V_o(s)}{V_{In}(s)} \equiv A_V(s)}$

Ex :- find 3dB freq. « $f_{3dB}$ » for this $T(s)$ ??

$$T(s) = \frac{5s}{2+3s}$$

← XP نحاول أبسط ال $T(s)$ لـ صورة أحد ال (forms) السابقة :-

$$\Rightarrow T(s) = \frac{5s}{2(1+\frac{3}{2}s)} = \frac{5 \times \frac{2}{3} \times \frac{3}{2} \times s}{2(1+\frac{3}{2}s)}$$

$$= \frac{5 \times \cancel{2}/3}{\cancel{2}} \times \frac{\frac{3}{2}s}{1+\frac{3}{2}s} = \frac{5}{3} \times \frac{\frac{2}{3}s}{1+\frac{2}{3}s}$$

$$\Rightarrow \tau = \frac{3}{2} \quad , K = \frac{5}{3}$$

$$\Rightarrow f_{3dB} = \frac{1}{2\pi\tau} = 0,2387 \ HZ \ . \ !!$$

في الحقيقة قيمة (Practical) بس طبيعة الأرقام بالسؤال

# Time Response :-

→ In general In Amplifier CKT :- Gain = $\frac{out}{In}$

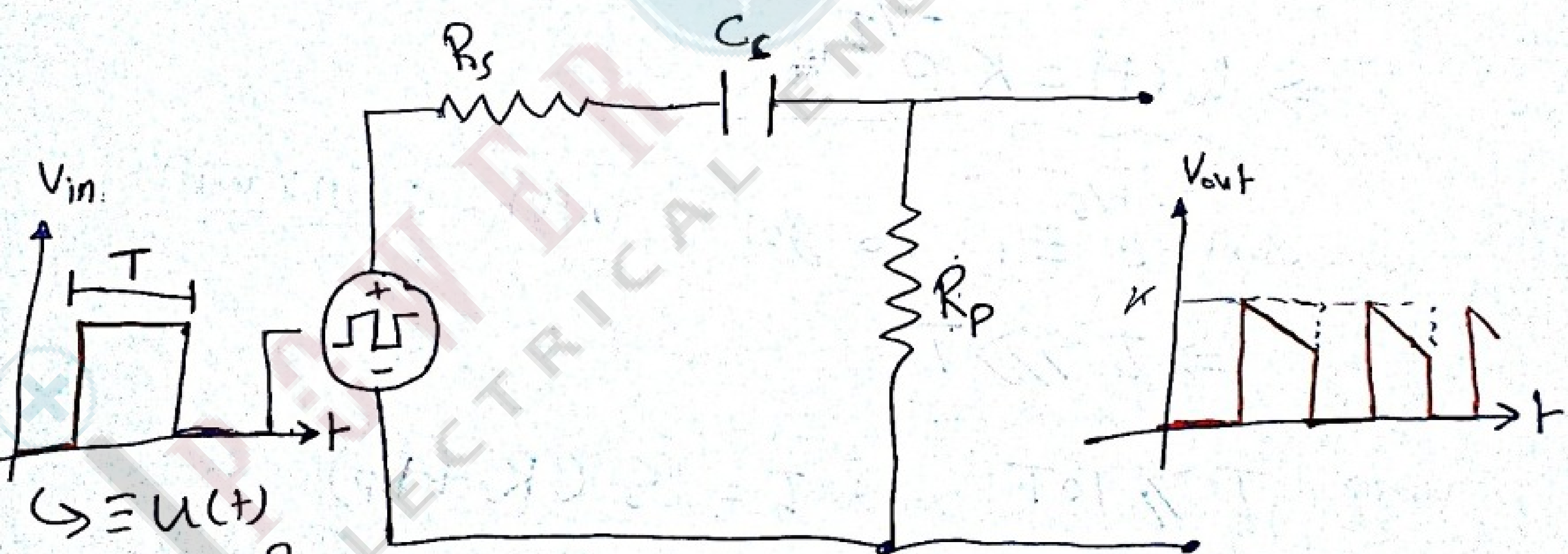
$\Rightarrow$ $\boxed{\text{Input} = \text{Gain} \times \text{output}}$

but Now we will study if $\boxed{\text{Input} \neq \text{Gain} \times \text{output}}$

* راح يكون عنا $C_c$ على الـ(Input) و راح يكون كمان $C_L$ على الـ output

$\Rightarrow$ we will study 2 circuits :- ① In-CKT ② out-CKT

1. Input circuit :-




↳ ≡ u(t)
unit step.

| Time domain | | S-domain |
|---|---|---|
| $V_{in}(t) = u(t)$ | $\xrightarrow{\text{by Laplace}}$ | $V_{in}(s) = \frac{1}{s}$ |

we know that from freq. responce $\Rightarrow$ $\boxed{\tau = R_{th}\, C = (R_p + R_s) C_c}$

and $K = |A_v| = \frac{R_p}{R_p + R_s}$ $\Rightarrow T(s) = K \times \frac{s\tau}{1 + s\tau}$

$$\Rightarrow T(s) = \frac{V_o(s)}{V_{in}(s)} = K \frac{s\tau}{1+s\tau}$$

$$\Rightarrow V_o(s) = K \frac{s\tau}{1+s\tau} * V_{in}(s)$$

but the $V_{in}(s) = u(t) = \frac{1}{s}$

$$\Rightarrow V_o(s) = K \times \frac{\cancel{s}\tau}{1+s\tau} \times \frac{1}{\cancel{s}}$$

$$V_o(s) = K \times \frac{\tau}{1+s\tau} = \boxed{K \times \frac{1}{\frac{1}{\tau} + s}}$$

$\Rightarrow$ tack the Inverse Laplace

$$\Rightarrow \boxed{V_o(t) = K e^{-t/\tau}}$$

we want $\boxed{e^{-t/\tau} \cong 1}$ to get $\boxed{\text{Input} = \text{Gain} \times \text{output}}$

$$\Rightarrow \tau >>> T$$

# Asume $\boxed{\tau \geq 10T}$ ; $\tau = C_s(R_s + R_p)$

$$\Rightarrow C_s(R_s + R_p) \geq 10T$$

$$\Rightarrow \boxed{C_s \geq \frac{10T}{R_s + R_p}} \Rightarrow C_c \uparrow \Rightarrow f_L \downarrow \Rightarrow B\uparrow \Rightarrow \underline{\underline{good}}$$

imp

$$\Rightarrow \tau \leq \frac{T}{10}$$

$$\Rightarrow C_L (R_S \parallel R_L) \leq \frac{T}{10}$$

$$\Rightarrow \boxed{C_L \leq \frac{T}{10(R_S \parallel R_L)}}$$ حفظ

$C_L \downarrow \Rightarrow f_H \uparrow \Rightarrow B \uparrow \Rightarrow$ good

$$\Rightarrow \boxed{C_C \gg C_L}$$

① because we want to get large Bandwidth.

② and get good Time response. ~~[illegible]~~

$$G = \frac{V_o}{V_{in}}$$

* Frequancy response for BJT ga

أول ال (chapter) كنا ندرس ال (circuits) بشكل عام بس
هلا رح نتخصص بالترانزستور نفسه.

BJT :-

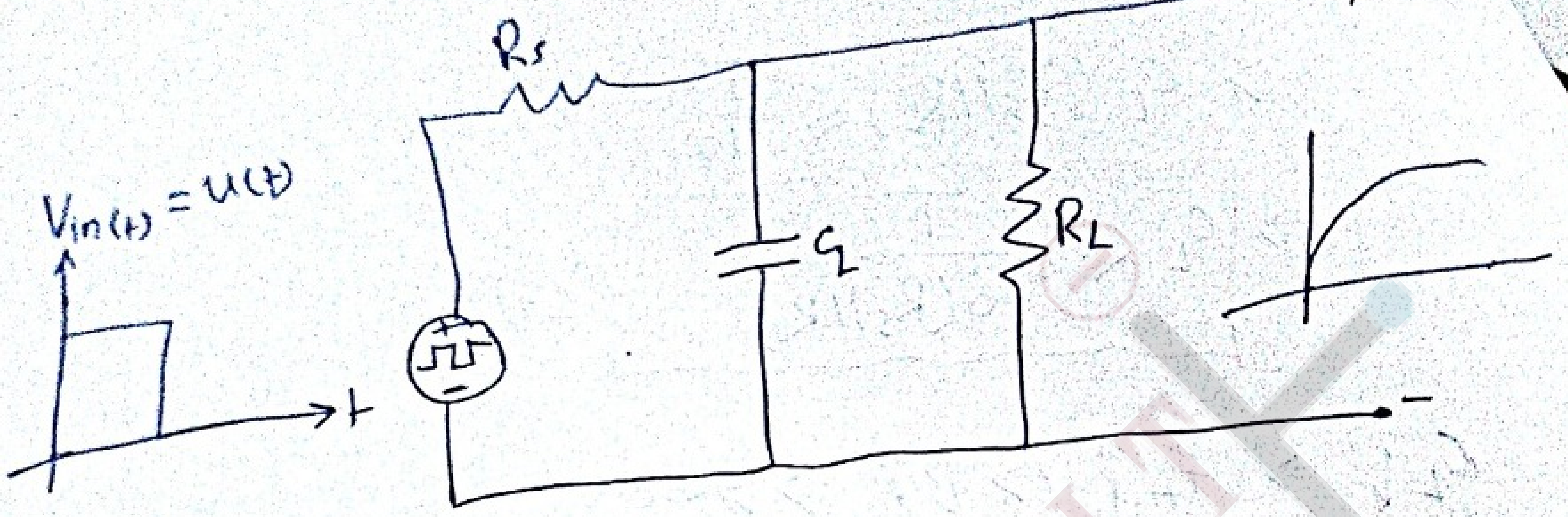
→ at DC ⇒ $f = 0$

⇒ current gain « short circuit current gain » $= \beta = \frac{I_C}{I_B}$

→ at Low freq. and Mid band freq. ga

⇒ current gain « short circuit current gain » $= \beta = \frac{I_C}{I_B}$

[2] output circuit :-




$$\frac{V_o(s)}{V_{in}(s)} = K * \frac{1}{1+s\tau} \quad \& \quad \tau = C_L (R_s // R_L)$$

$$u(t) \longrightarrow \frac{1}{s}$$

$$\Rightarrow T(s) = \frac{V_o(s)}{V_{in}(s)} = K * \frac{1}{1+s\tau} \quad \text{but } V_{in}(s) = u(t) = \frac{1}{s}$$

$$\Rightarrow V_o(s) = V_{in}(s) * K * \frac{1}{1+s\tau}$$

$$\Rightarrow V_o(s) = \frac{1}{s} \times K \times \frac{1}{1+s\tau}$$

$\Rightarrow$ by Inverce LaPlace

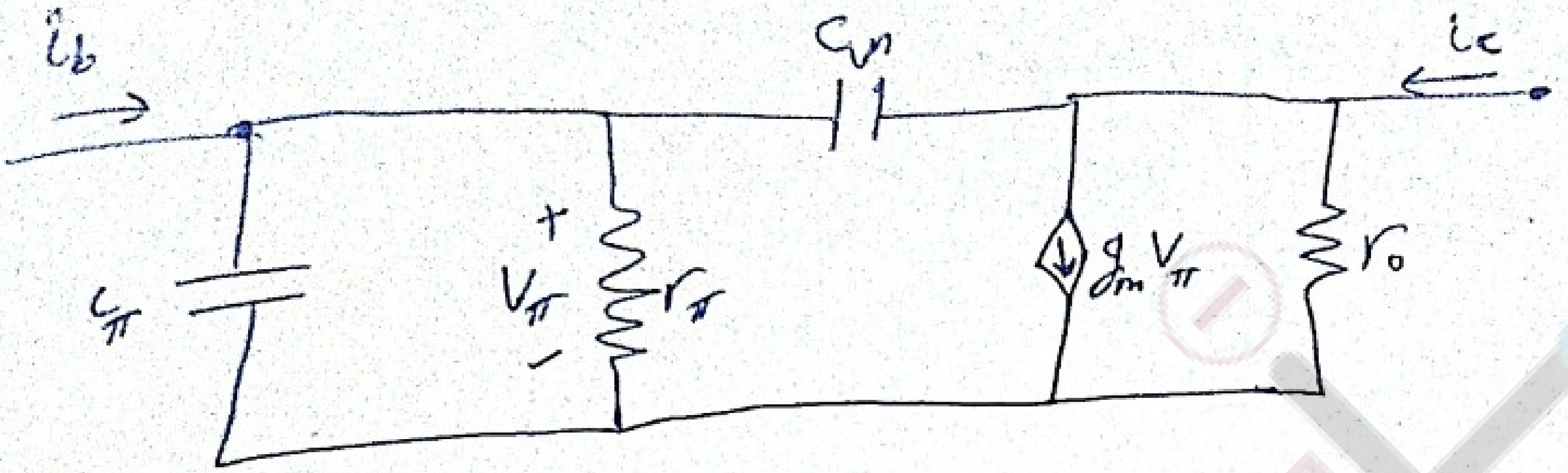
$$\Rightarrow \boxed{V_o(t) = K(1 - e^{-t/\tau})}$$

$\Rightarrow$ we want to $\boxed{e^{-t/\tau} \simeq 0}$ to get $\boxed{V_{in} = \text{Gain} \times V_{out}}$

$\Rightarrow \tau <<< T \Rightarrow$ Assume $\boxed{\tau \leq \frac{T}{10}}$ #

but $\tau = C_L (R_s // R_L)$

at High freq. range so $\beta \neq \frac{I_c}{I_B}$




$C_\pi$ :- Fowrward - biased Junction capacitor.

$C_M$ :- Revarsed - biased Junction capacitor.

* usually $C_M <<< C_\pi$ so $\beta \neq \frac{I_c}{I_B}$

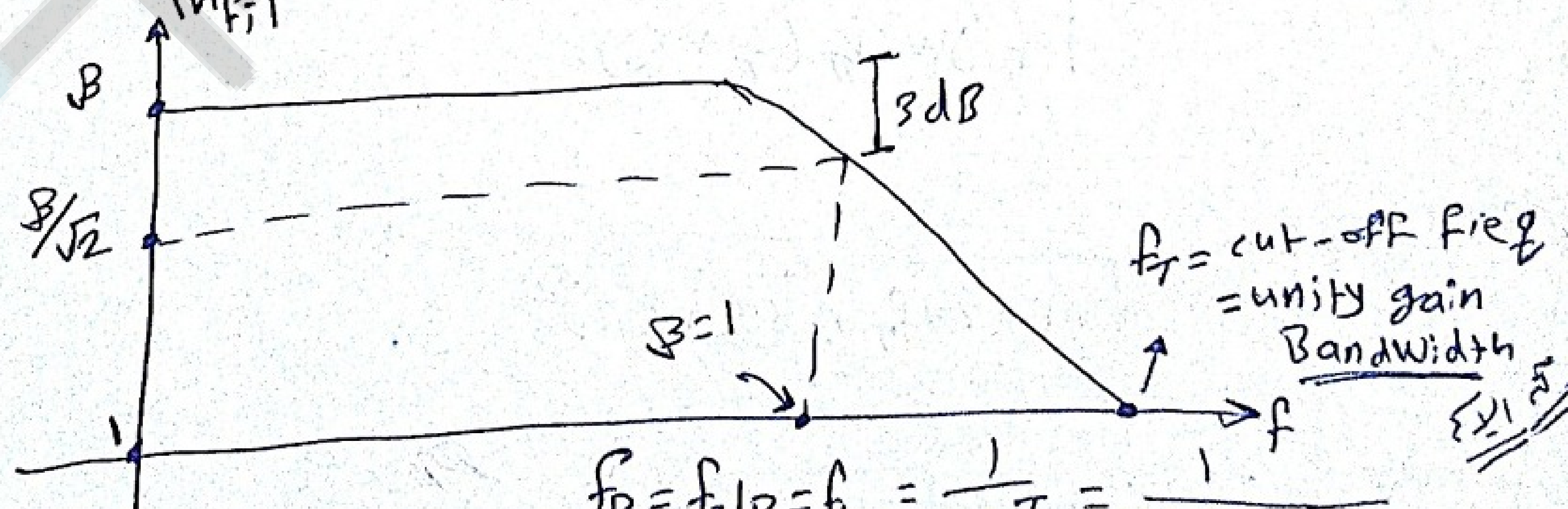
$$\boxed{h_{fe} = A_i = \frac{i_c}{i_b} \simeq \frac{\beta}{1 + jw r_\pi (C_\pi + C_M)}}$$

حفظ للامتحانات

إذا حاب تعرف اشتقاق القانون راجع الدفتر أو الكتاب.

$\Rightarrow \boxed{I_c = I_B \times h_{fe}}$ ; $\boxed{h_{fe} \equiv A_i}$

$$h_{fe} = A_i = \frac{\beta}{1 + \underbrace{jw}_{=s} \underbrace{r_\pi (C_\pi + C_M)}_{=\tau}} \equiv T(s) = K \times \frac{1}{1 + s\tau}$$



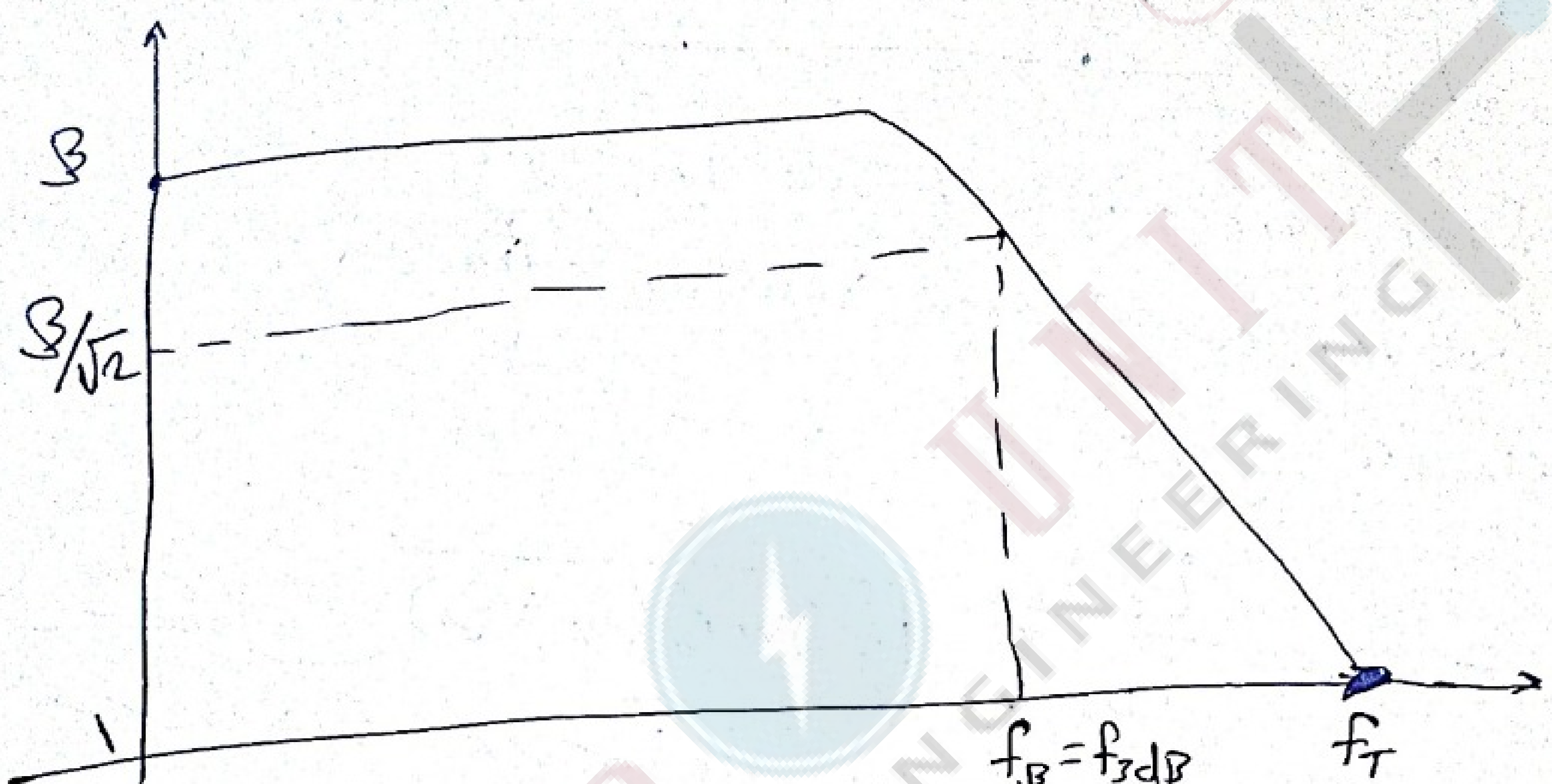

$$f_\beta = f_{3dB} = f_{h_{fe}} = \frac{1}{2\pi\tau} = \frac{1}{2\pi r_\pi (C_\pi + C_M)}$$

$\hookrightarrow$ beta - cut-off freq. or the Bandwith of Tra[nsistor]

إذا كان حجم الترانزستور صغير ⇐ ($C_\pi + C_\mu$) راح يكون قليل

⇐ راح نستخدمو في (High freq.) ⇐ ($f_\beta$) راح يكون كبير

⇐ ال (Bandwidth) راح يكون واسع ⇐ <u>good</u>




$f_\beta$ → Bandwidth of Transistor

$f_T$ → cut off freq. or unity gain Bandwidth $|h_{fe}(f_T)| = 1$

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

$$* \; h_{fe} = A_i = \frac{\beta}{1 + jw\, r_\pi (C_\pi + C_\mu)}$$

$$|h_{fe}| = \frac{\beta}{\sqrt{1 + (2\pi f_T\, r_\pi (C_\pi + C_\mu))^2}} = 1$$

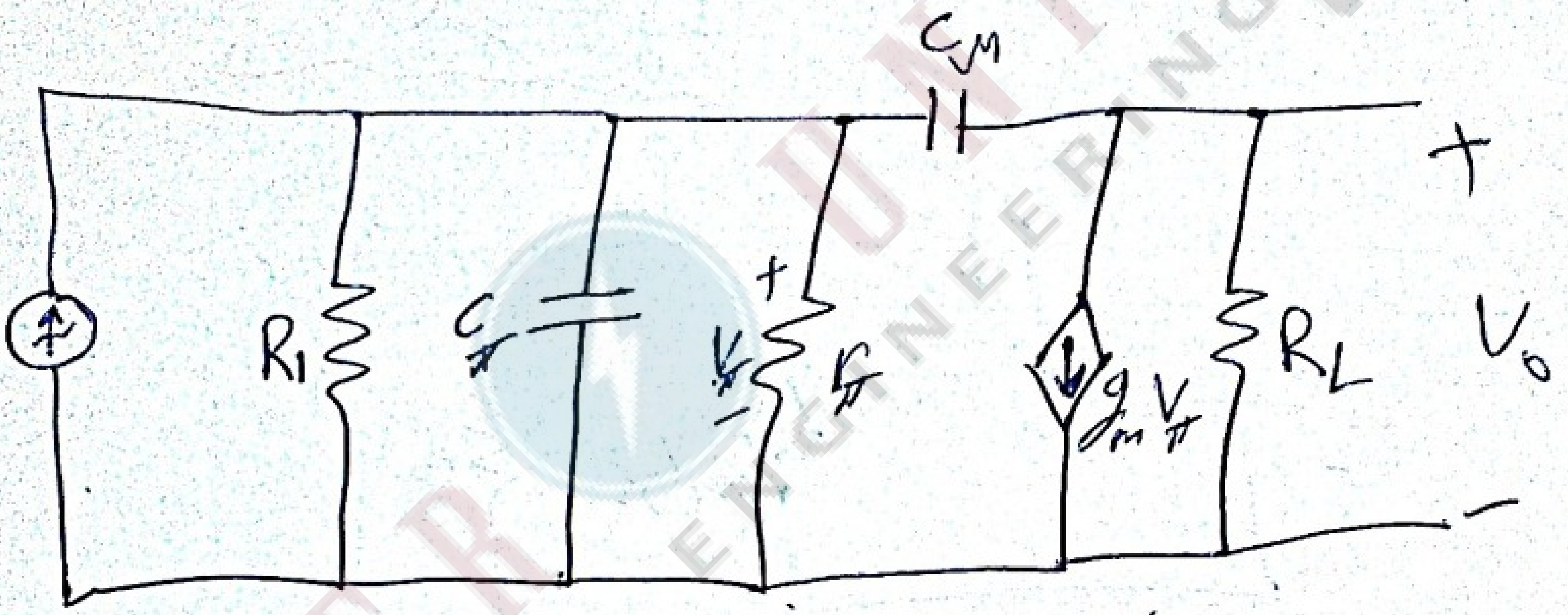
$$\Rightarrow \boxed{|h_{fe}| = \frac{\beta}{\sqrt{1 + (f_T / f_\beta)^2}} = 1}$$

$\boxed{f_T \gg f_\beta} \Rightarrow |h_{fe}| = \frac{\beta}{f_T / f_\beta} = 1$

$\Rightarrow \boxed{\beta = \frac{f_T}{f_\beta}} \Rightarrow \boxed{f_T = \beta \, f_\beta}$

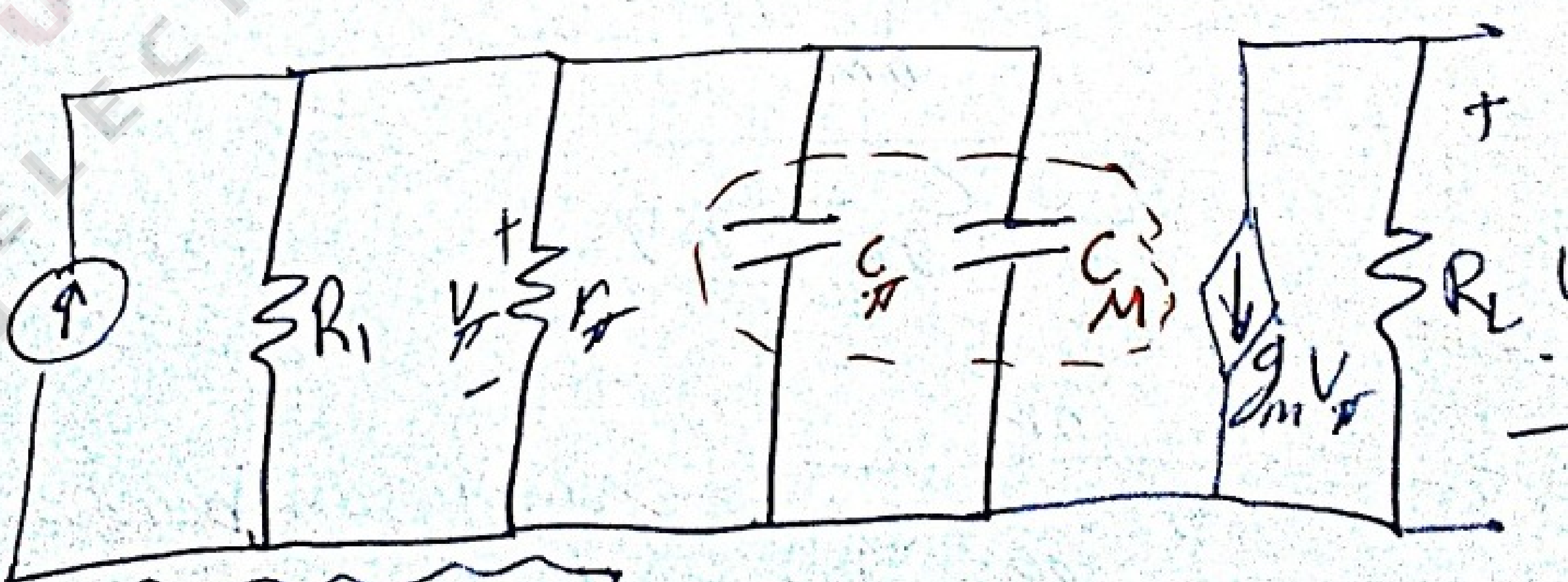
Miller effect «feedback effected» and Miller capacitor

Ex:-




$C_M \ll C_\pi$ but we can not Ignor $C_M$ due to Miller effect.

$\Rightarrow$ =




$\boxed{C_M = C_\mu * [1 + g_m R_L]}$ $\Rightarrow$ In general

$\boxed{C_M = C_M * [1 + |V_{out}|]}$

$\boxed{\hookrightarrow \text{let } V_\pi = 1}$

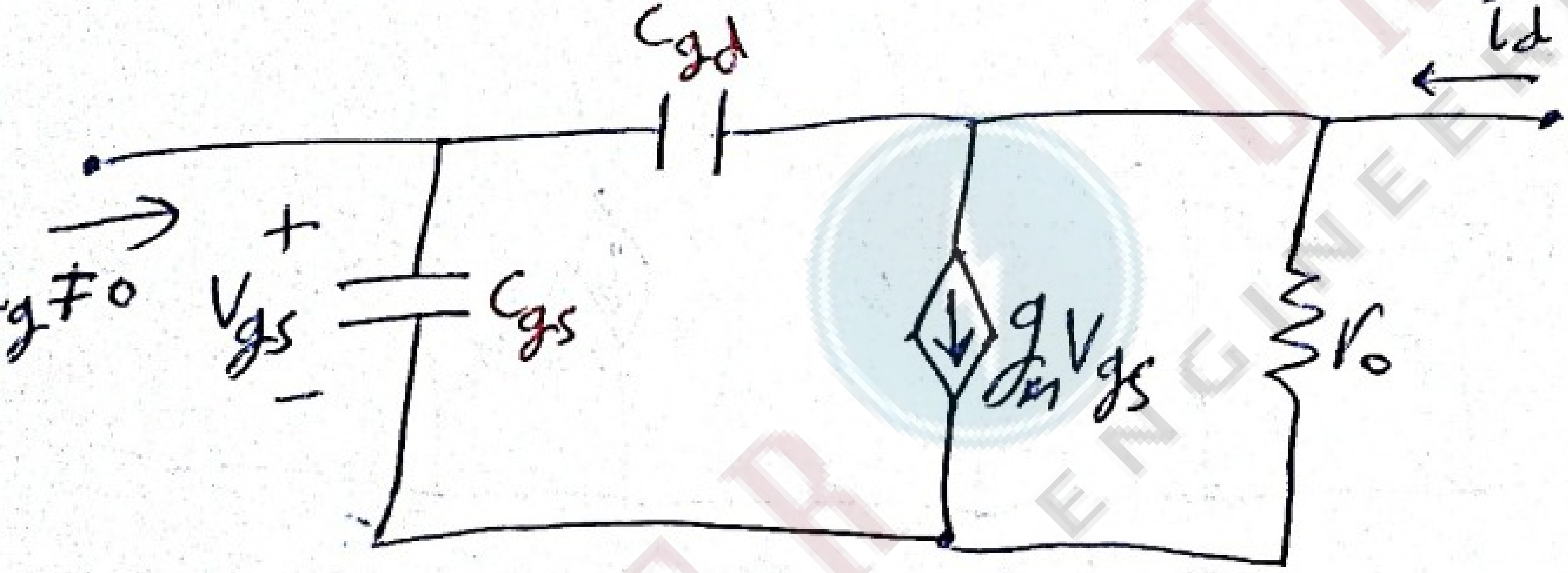
* The frequancy response of FET :-

→ at DC → $f = 0$ $\quad A_i = \frac{i_c}{i_g} = \infty$

→ at Low freq. and Midband freq

$$A_i = \frac{i_c}{i_g} = \infty$$

→ at High freq :- $\boxed{i_g \neq Zero}$




⇒ short circuit current gain «$A_i$» $= \frac{i_d}{i_g}$

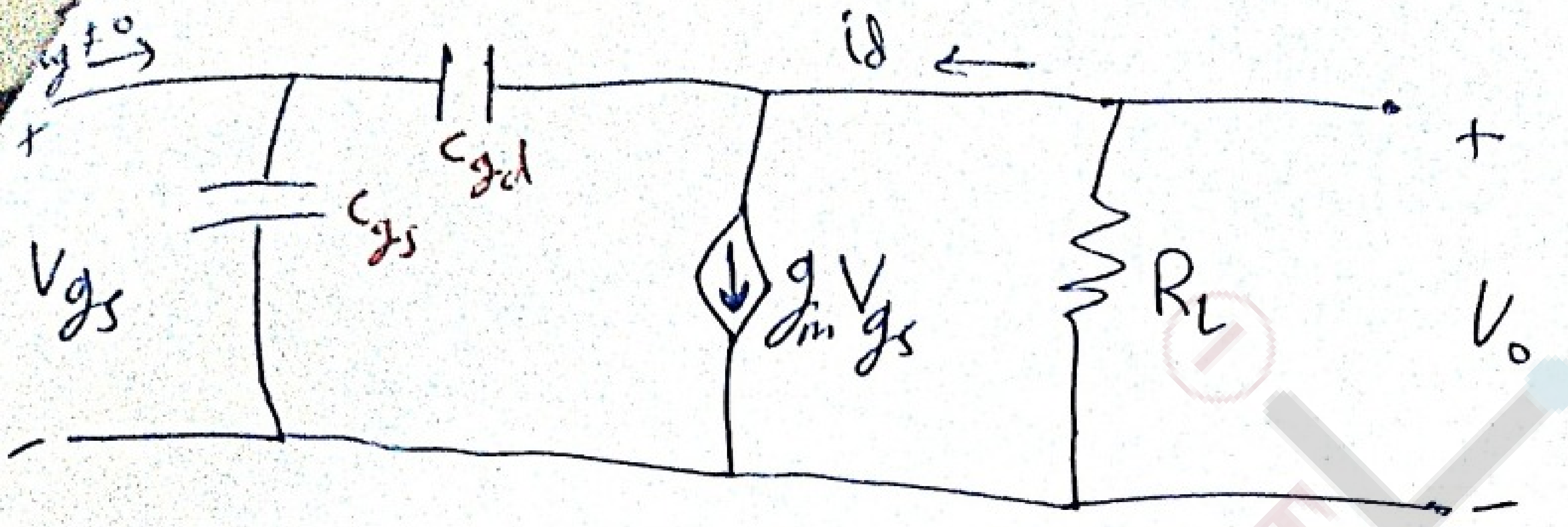
$$\Rightarrow \boxed{A_i = \frac{g_m}{jw(C_{gd} + C_{gs})}}$$

حفظ

راجع الدفتر لمعرفة
طريقة الإشتقاق

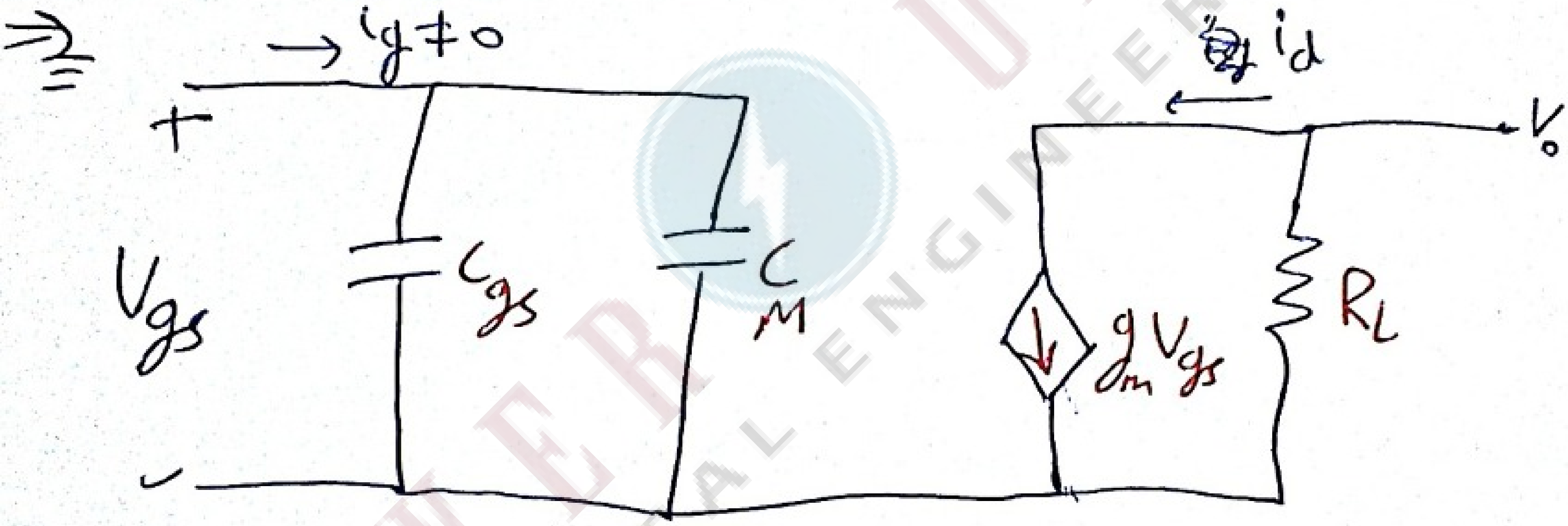
$$\boxed{f_T = \frac{g_m}{2\pi(C_{gd} + C_{gs})}}$$ → unity gain bandwidth.

Miller effect and Miller capacitor FET :-




$C_{gs} > C_{gd}$ but we can't ignor $C_{gs}$ due to Miller effect.

$\Rightarrow$




$$\boxed{C_M = C_{gd} * (1 + g_m R_L)}$$

Done By :- Anas Kat3
"Electrical Engineering"

تلخيص
لما الشابتر

+ حل ال HW اشتاد السرع.

AmPlifier
Final material

Am... Kars

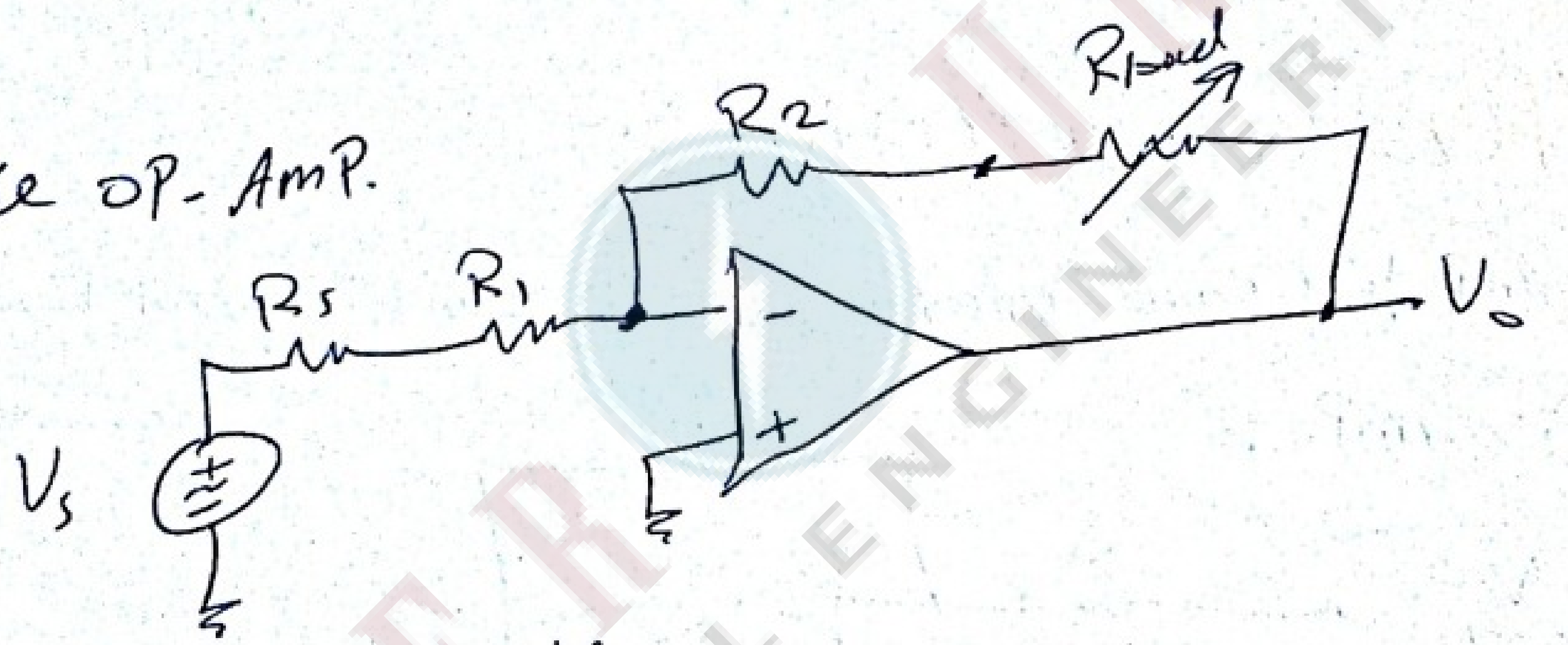
☒ Voltage to current converter :-

→ use Resistor (R) then you can change the Voltage to current. by ohm's low $I = \frac{V}{R}$

but the current (I) will change with $R_{load}$

⇒ so it's Not solution to change from Volte to current.

→ use OP-AmP.



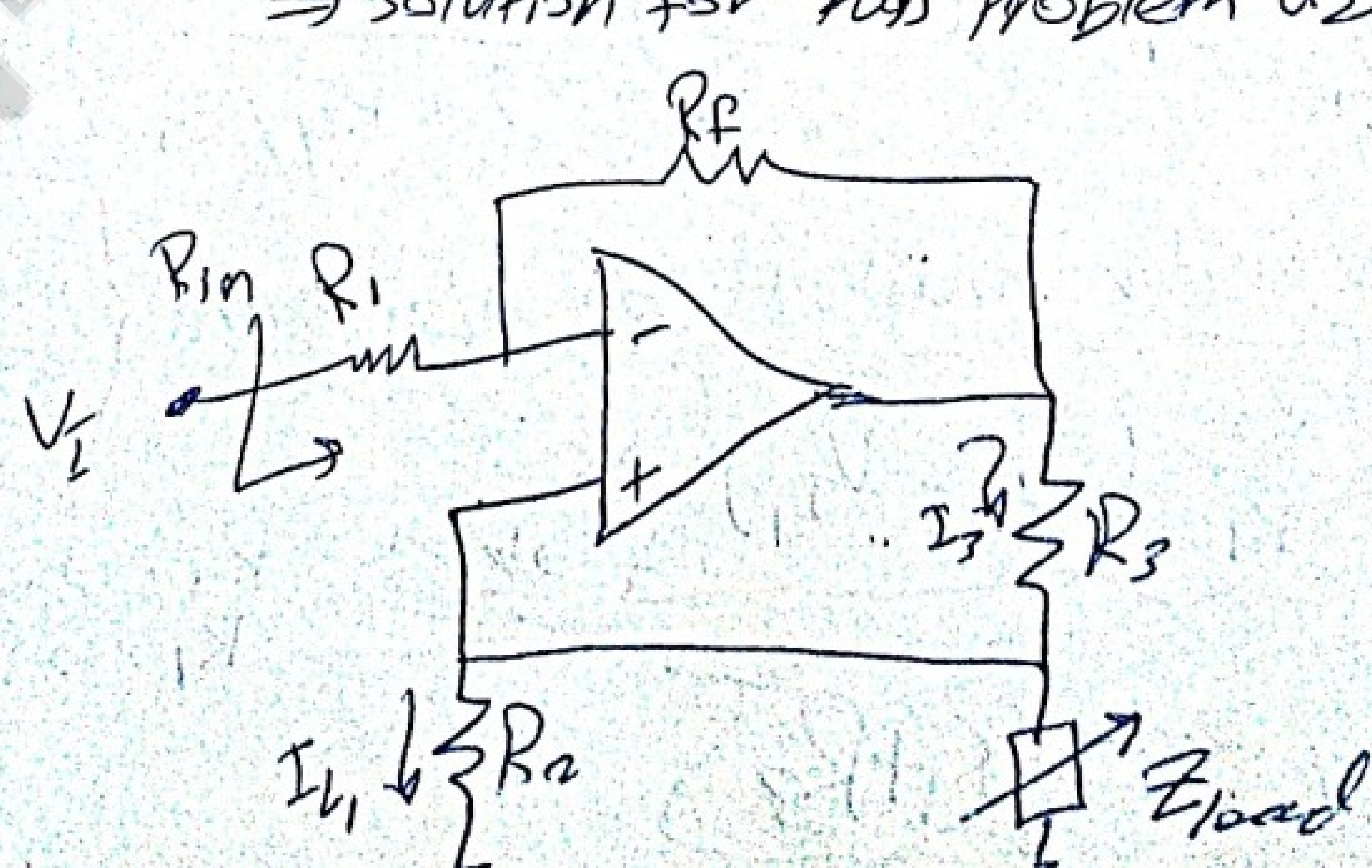

$$I_o = \frac{V_s}{R_s + R_1}$$

⇒ $(I_o)$ will Not change by changing the load ⇒ goo

but the Problem:- the load can't be connected to the gro

⇒ solution for this Problem use Transform

→ use



$$\Rightarrow I_L\left(\frac{R_f Z_L}{R_1 R_3} - 1 - \frac{Z_L}{R_2}\right) = V_I\left(\frac{R_f}{R_1 R_3}\right)$$

$\Rightarrow$ by desighn must to be $\boxed{\dfrac{R_f}{R_1 * R_3} = \dfrac{1}{R_2}}$

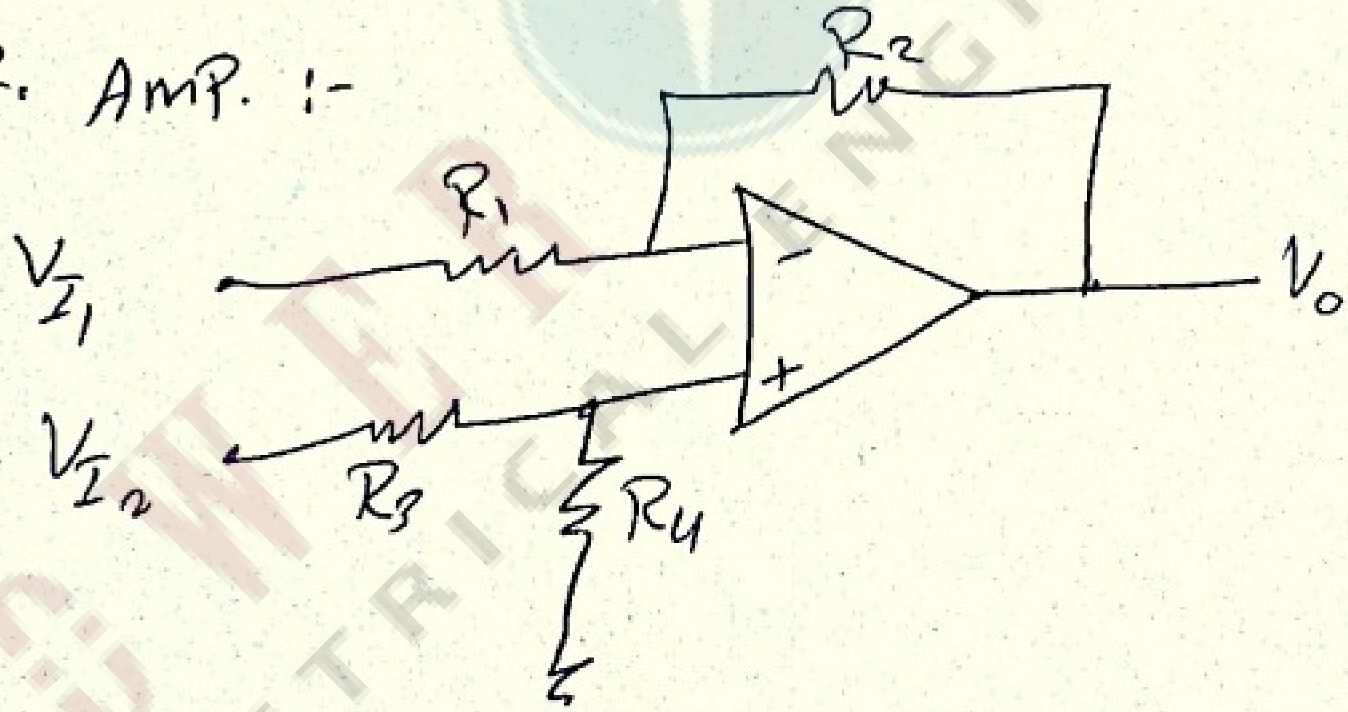
$$\Rightarrow \boxed{I_L = -V_I\left(\frac{R_f}{R_1 R_2}\right)} \Rightarrow \boxed{I_L = -\frac{V_I}{R_2}} \#$$

and $R_{in} = \dfrac{R_1 R_x}{R_1 + R_x}$

## *[7] Differance Amplifier 3a

Basic OP-AMP has same function but we can't control the gain.

$\Rightarrow$ Diff. Amp. :-




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

$\Rightarrow$ by desighn must to be the ratio $\boxed{\dfrac{R_2}{R_1} = \dfrac{R_4}{R_3}} \#$

$\Rightarrow \boxed{V_o = \dfrac{R_2}{R_1}\left(V_{I_2} - V_{I_1}\right)} \# \rightarrow$ اترط $R_2 \rightarrow R_4$, $R_1 \rightarrow R_3$ or $\dfrac{R_2}{R_1} = \dfrac{R_4}{R_3}$

$\Rightarrow \boxed{R_{in} = 2R_1} \# = \boxed{R_1 + R_3}$

⇒ for diff. Amplifier :-

# $\boxed{V_o = \frac{R_2}{R_1}(V_{I_2} - V_{I_1})}$ and $\boxed{R_{in} = 2R_1}$ #

⇒ as we see, we have the Problem :-

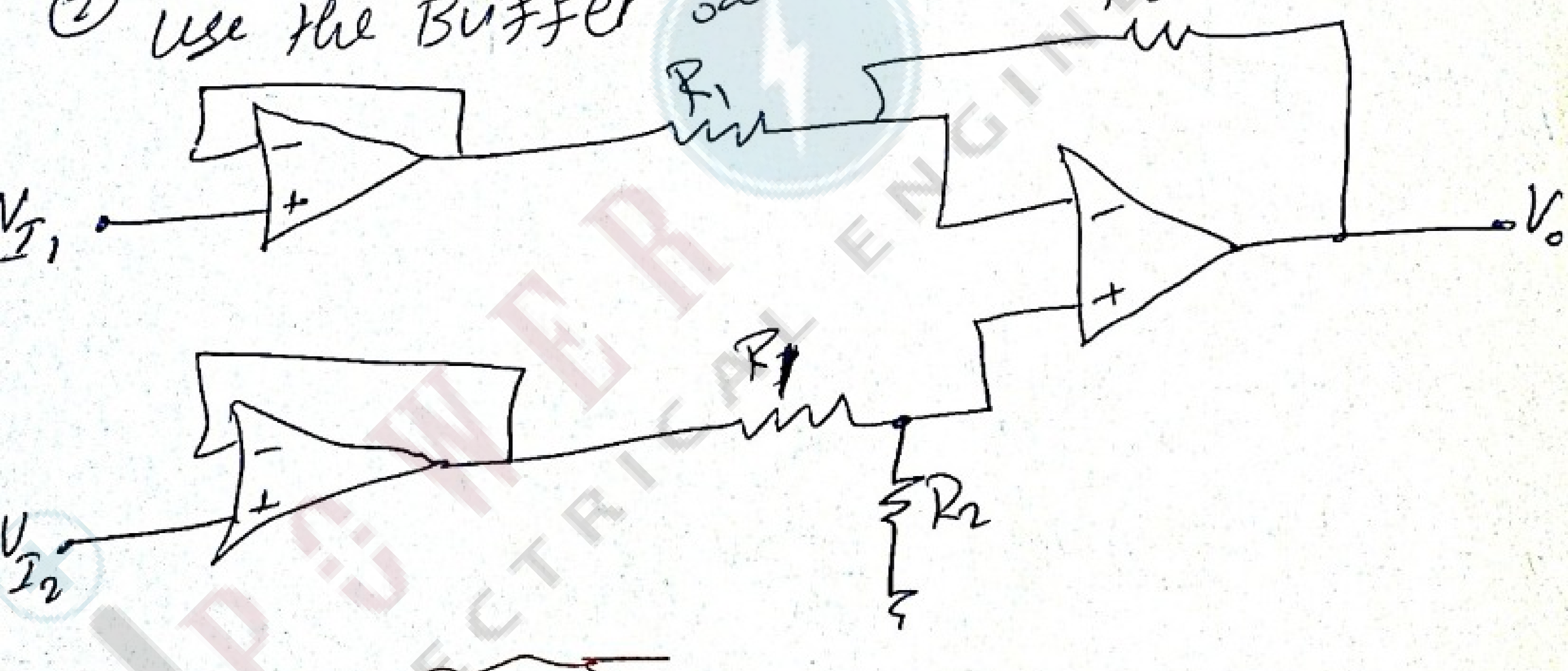
if $R_1 \uparrow$ then $R_{in} \uparrow$ but the gain $(\frac{R_2}{R_1}) \downarrow$

⇒ we have :- ① $R_{in}$ Problem and ② gain $(\frac{R_2}{R_1})$ Problem

⇒ Solution for this Problem :-

① Increase $(R_2)$ but this Need the user to Increase $(R_4)$ by the same value ⇒ ~~will~~ witch is ImPractical.

or ② use the Buffer




⇒ $\boxed{R_{in} = \infty}$ good

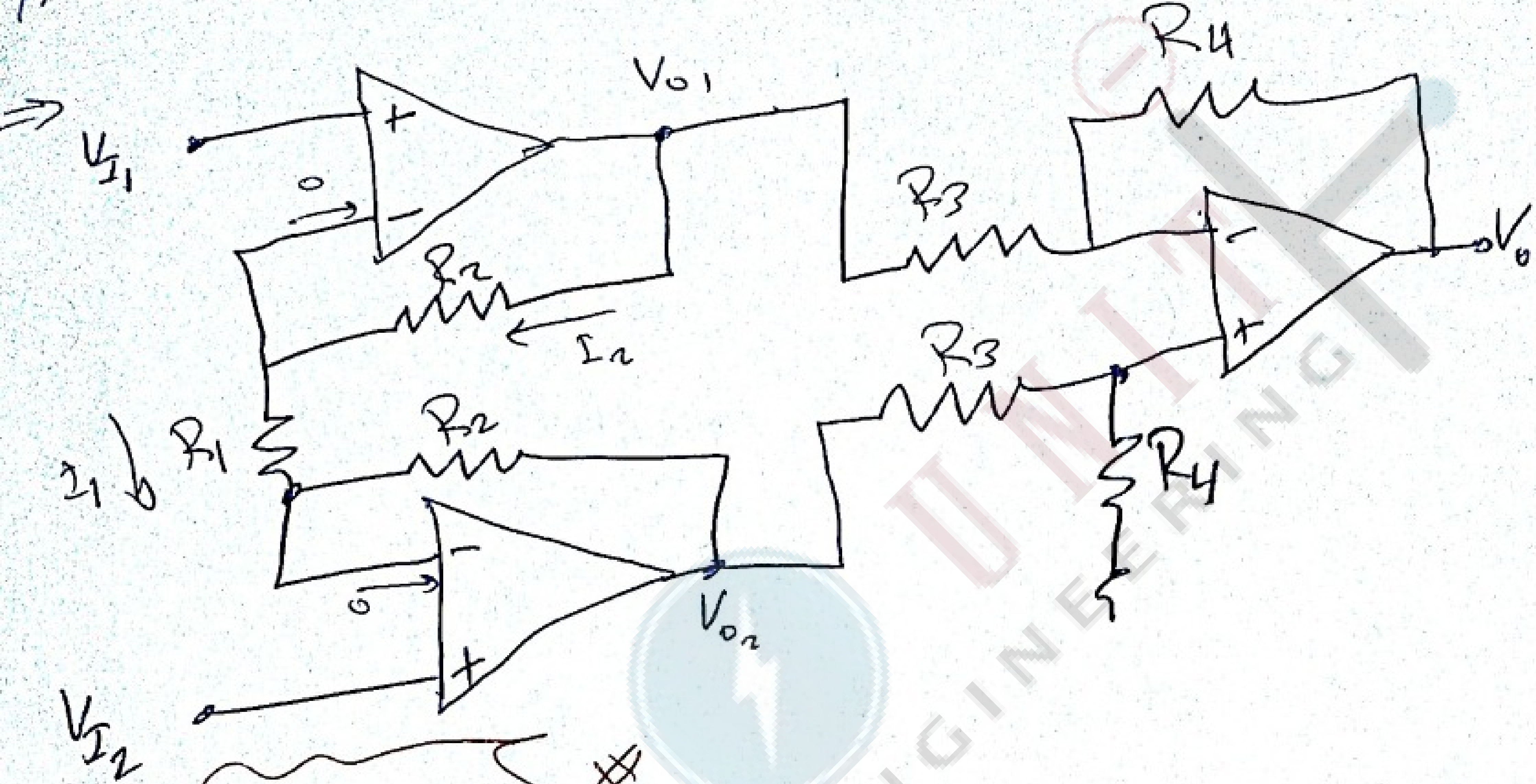
but this solution solve the $(R_{in})$ Problem but it does Not solve the gain $(\frac{R_2}{R_1})$ Problem

or ③ use (Instrumentation) Amplifier

⇒ [8] Instrumentation Amplifier :-

use as a difference Amp. to solve ($R_{in}$) and gain ($\frac{R_2}{R_1}$) problems.

⇒




$\boxed{R_{in} = \infty}$ #

$$V_{o_1} = \left(1+\frac{R_2}{R_1}\right)V_{I_1} - \frac{R_2}{R_1}V_{I_2}$$

$$V_{o_2} = \left(1+\frac{R_2}{R_1}\right)V_{I_2} - \frac{R_2}{R_1}V_{I_1}$$

$$\Rightarrow V_o = \frac{R_4}{R_3}\left(V_{o_2} - V_{o_1}\right)$$

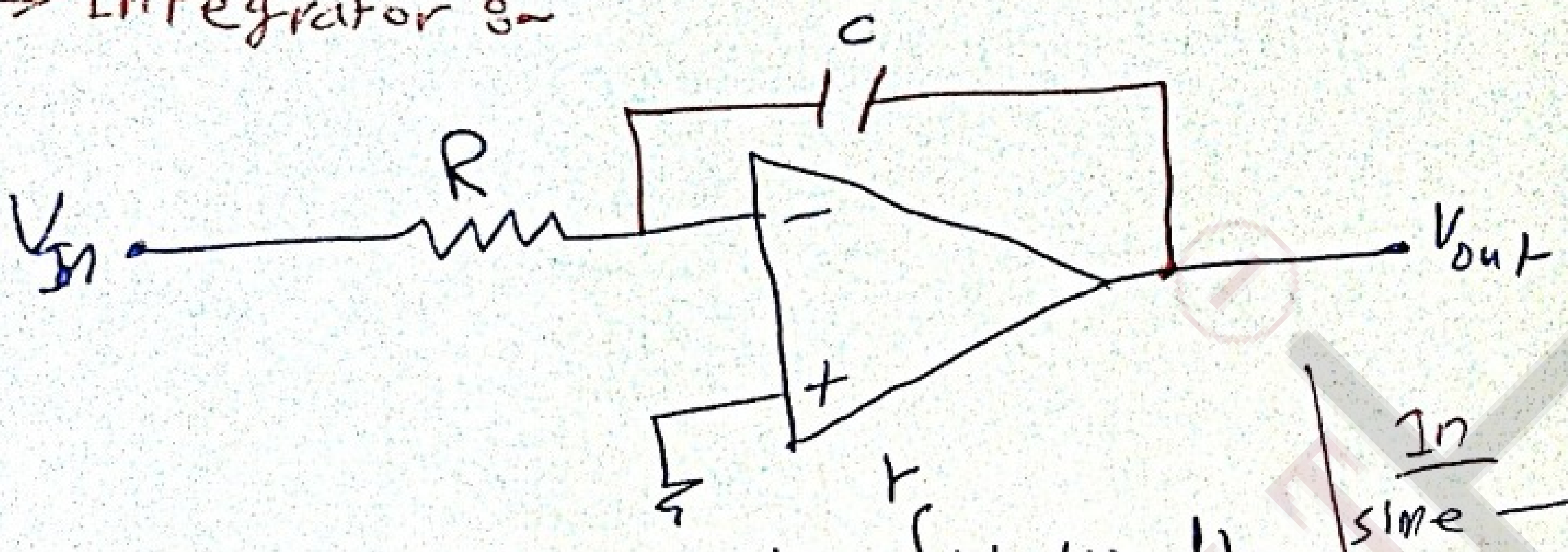
$$\Rightarrow V_o = \frac{R_4}{R_3}\left(1+\frac{2R_2}{R_1}\right)\left(V_{I_2} - V_{I_1}\right)$$

$R_2, R_3, R_4$ are constant, <u>$R_1$ only variable</u>

⇒ The user can control the gain by change only ($R_1$), $\boxed{R_{in} = \infty}$ ⇒ good design.

# Integrator and differentiator :-

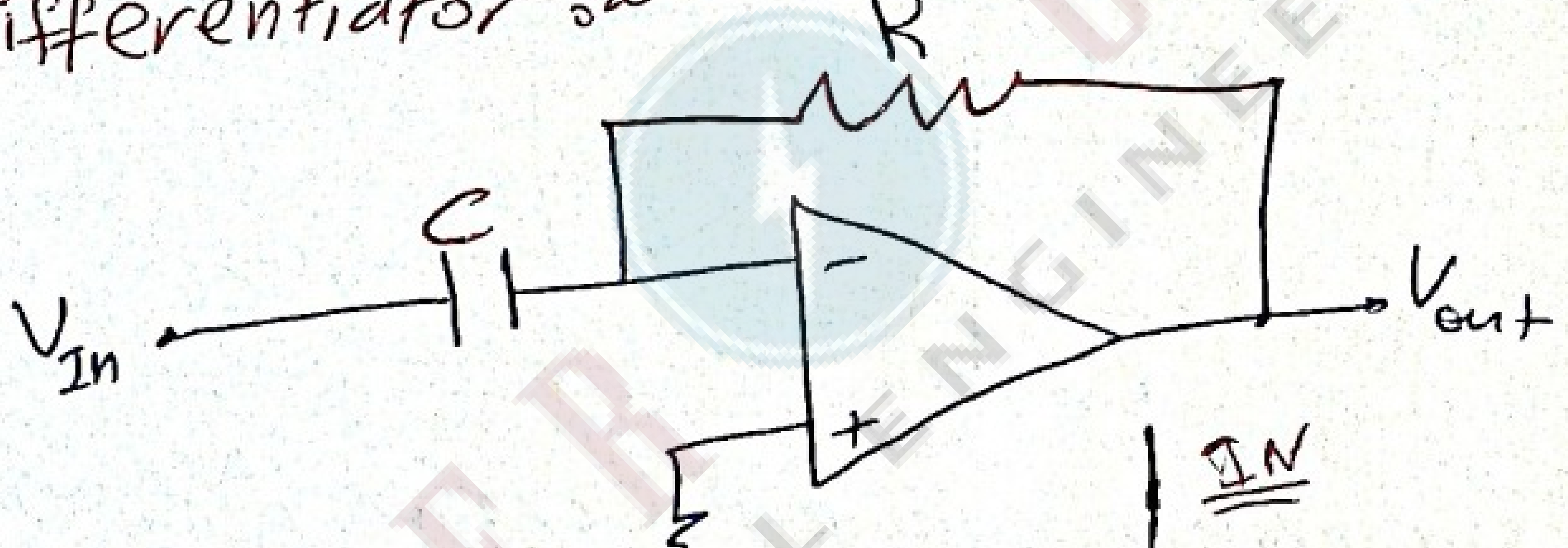
## → Integrator :-




$$V_{out}(t) = V_c - \frac{1}{RC}\int_0^t V_{In}(t)\,dt$$

| In | out |
|---|---|
| sine → | sine lead $\frac{\pi}{2}$ |
| square → | saw. |

## → Differentiator :-

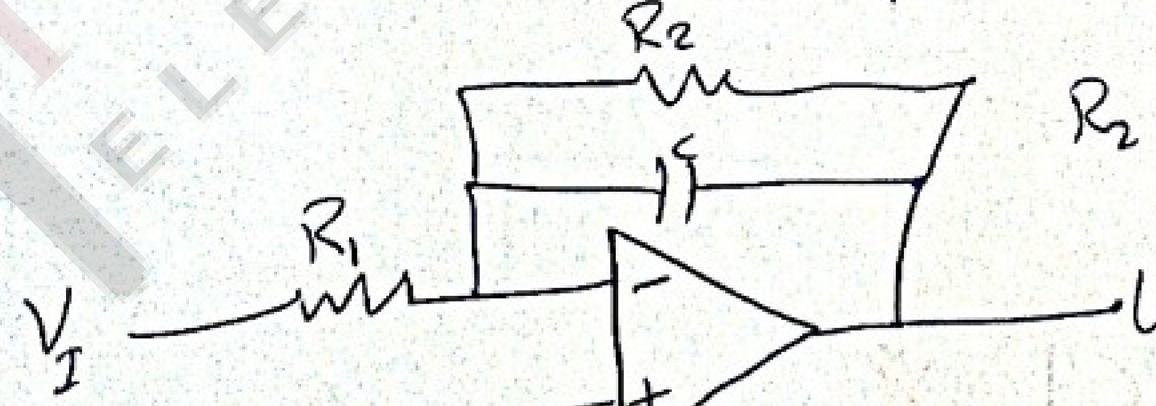



| IN | out |
|---|---|
| DC → | Zero |
| sin → | sine lagg $\frac{\pi}{2}$ |
| saw → | square |

$$V_{out}(s) = -sCR\,V_I(s)$$

$$V_{out}(t) = -RC\,\frac{dV_I(t)}{dt}$$

EX :-




$R_2 \neq \infty$

what is the condition that make this ckt an Integrator

$$\Rightarrow \frac{V_0(s)}{V_I(s)} = -\frac{R_2 \parallel \frac{1}{sC}}{R_1} = \frac{-\frac{R_2 \times \frac{1}{sC}}{R_2 + \frac{1}{sC}}}{R_1}$$

$$\Rightarrow = -\frac{R_2 * \frac{1}{SC}}{R_1\left(R_2+\frac{1}{SC}\right)} \times \frac{SC}{SC}$$

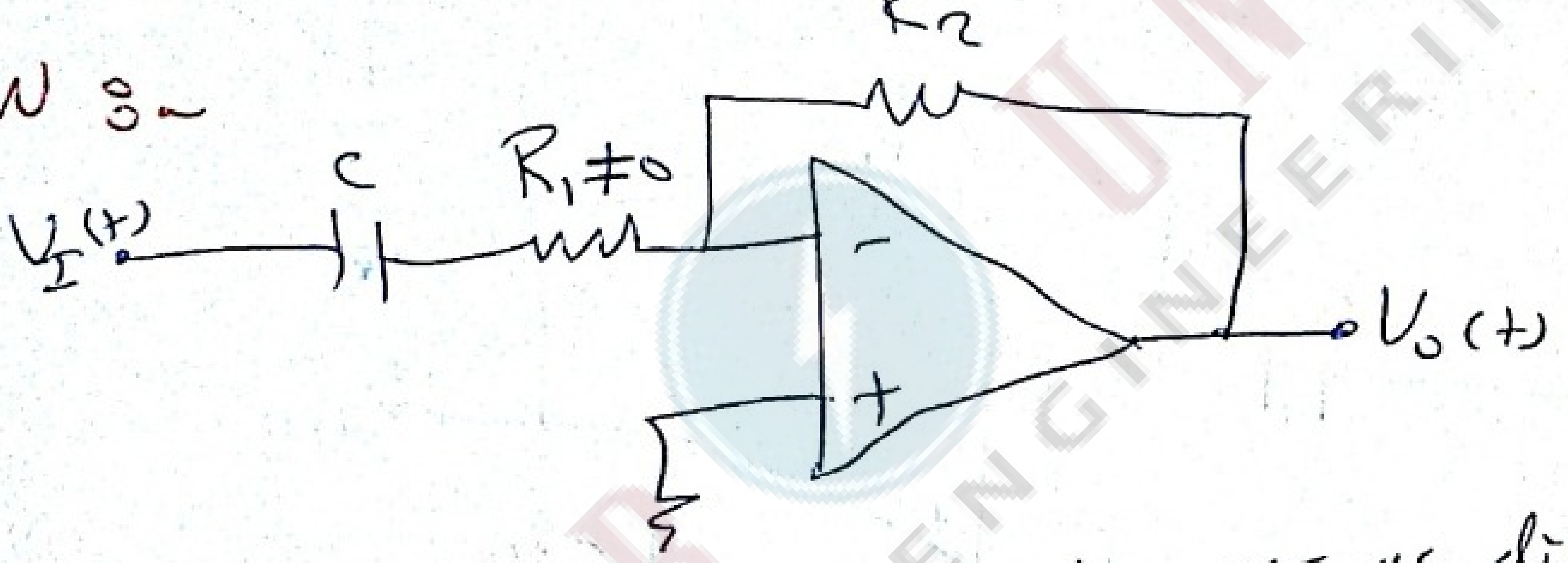
$$\Rightarrow = \frac{-R_2}{R_1(R_2SC+1)} \Rightarrow \frac{-1}{R_1SC}$$

$$\Rightarrow \boxed{R_2SC \gg 1} \#$$

this mean this work for <u>High freq.</u> #

Ex

H.W :-




What is the condition to make this CKT as differntiator?

$\Rightarrow$

$$\frac{V_o(s)}{V_I(s)} = -\frac{R_2}{R_1+\frac{1}{SC}} * \frac{SC}{SC} \Rightarrow \frac{V_o(s)}{V_I(s)} = -\frac{R_2SC}{R_1SC+1}$$

$$\Rightarrow V_o(s) = -\frac{R_2SC\,V_I(s)}{R_1SC+1}$$

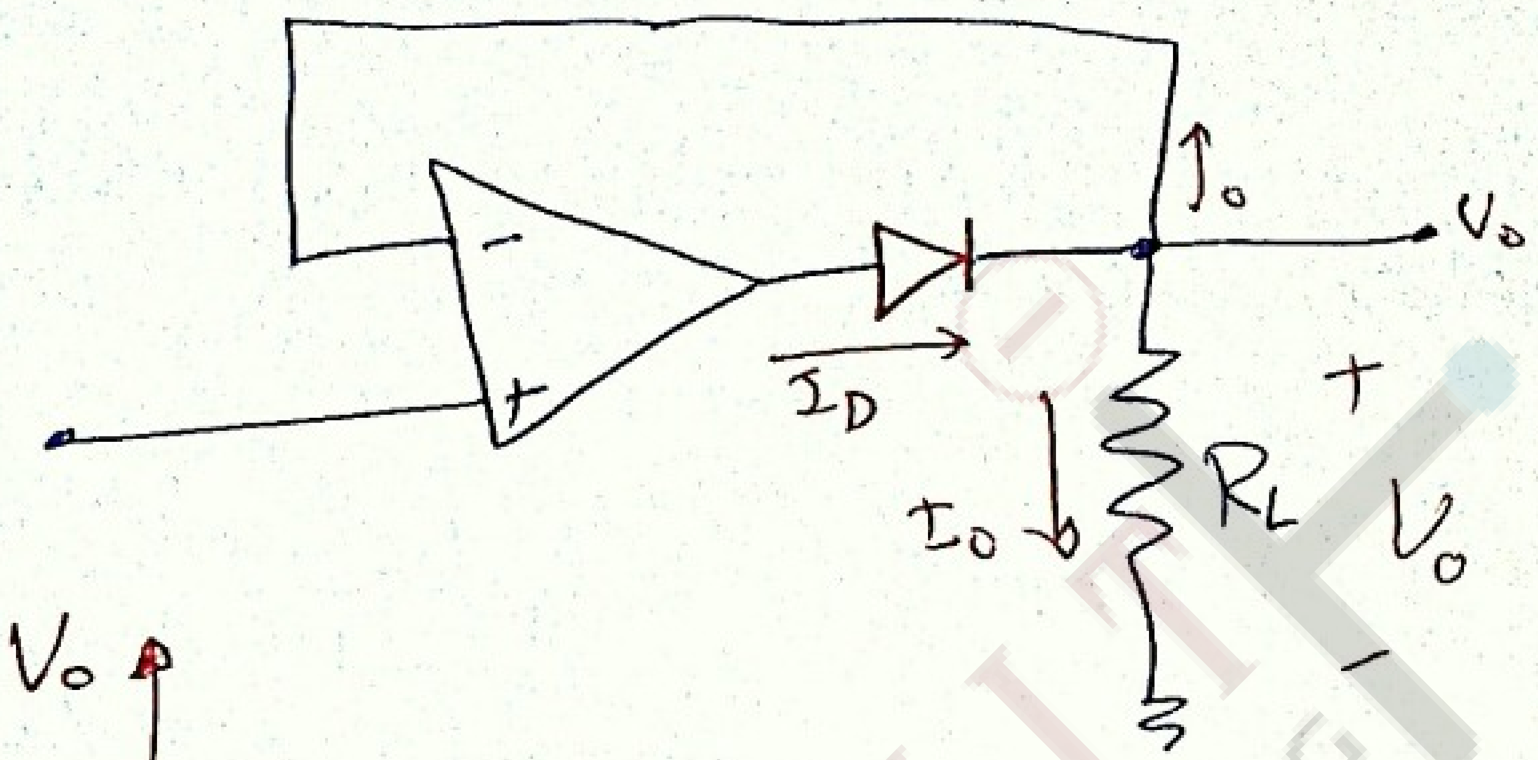
$$\Rightarrow \boxed{R_1SC \ll 1} \#$$

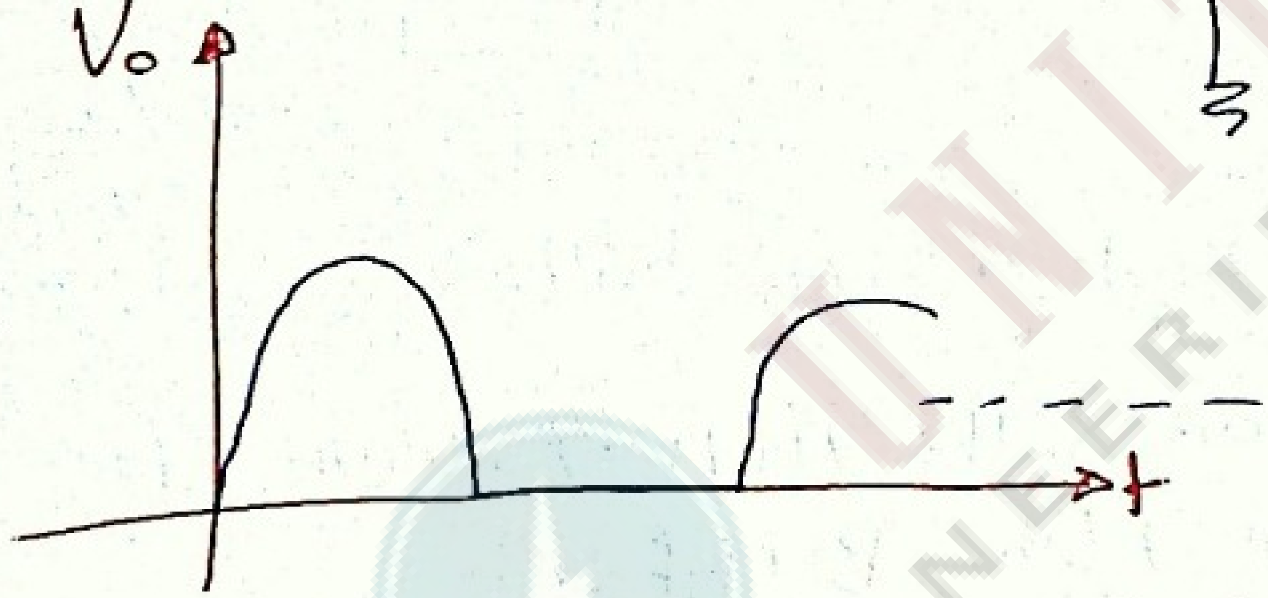
$\Rightarrow$ this mean this work for <u>low freq.</u> #

# Precision half-wave rectifier

→ Diode on :-
$V_o = V_L$

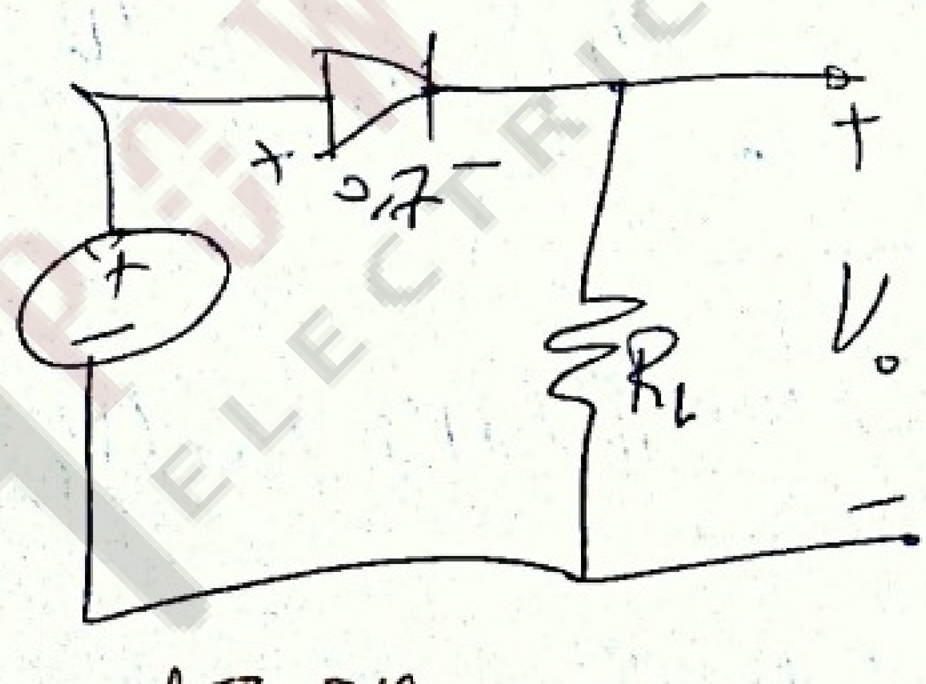
→ Diode off
$V_o = 0$

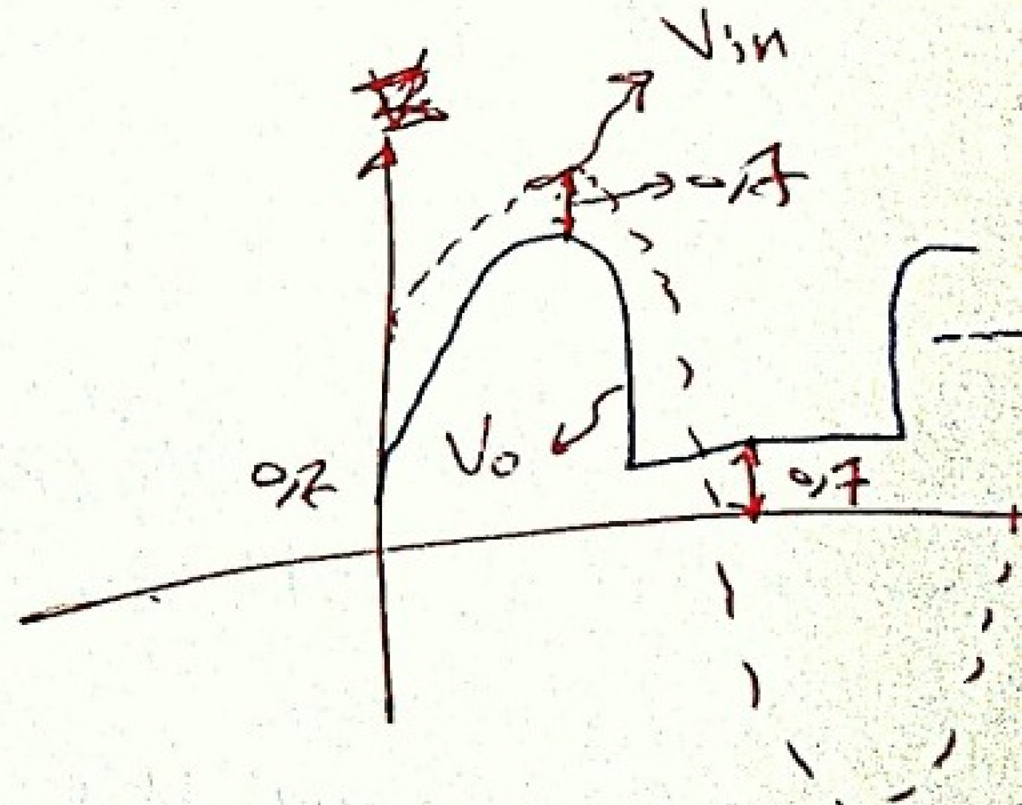



هون لا يوجد [drop Voltage (0.7)] زي الـ Half Wave

الاعتيادية اللي أخذناها بـ (electronics 1)



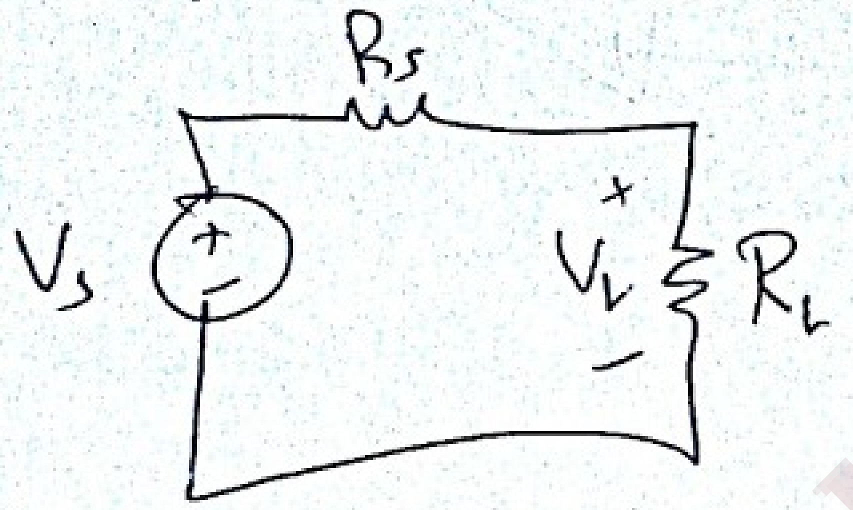

~~Diode on~~

* بس شو مطلوب هون انه لازم نعرفه كيف الـ rectifier

# III Referance Voltage Source

⇝ In typical Voltage source we have Problem

* Ⓐ load effect ⇒ $V_L$ will changing with change ($R_L$) due to $R_s$

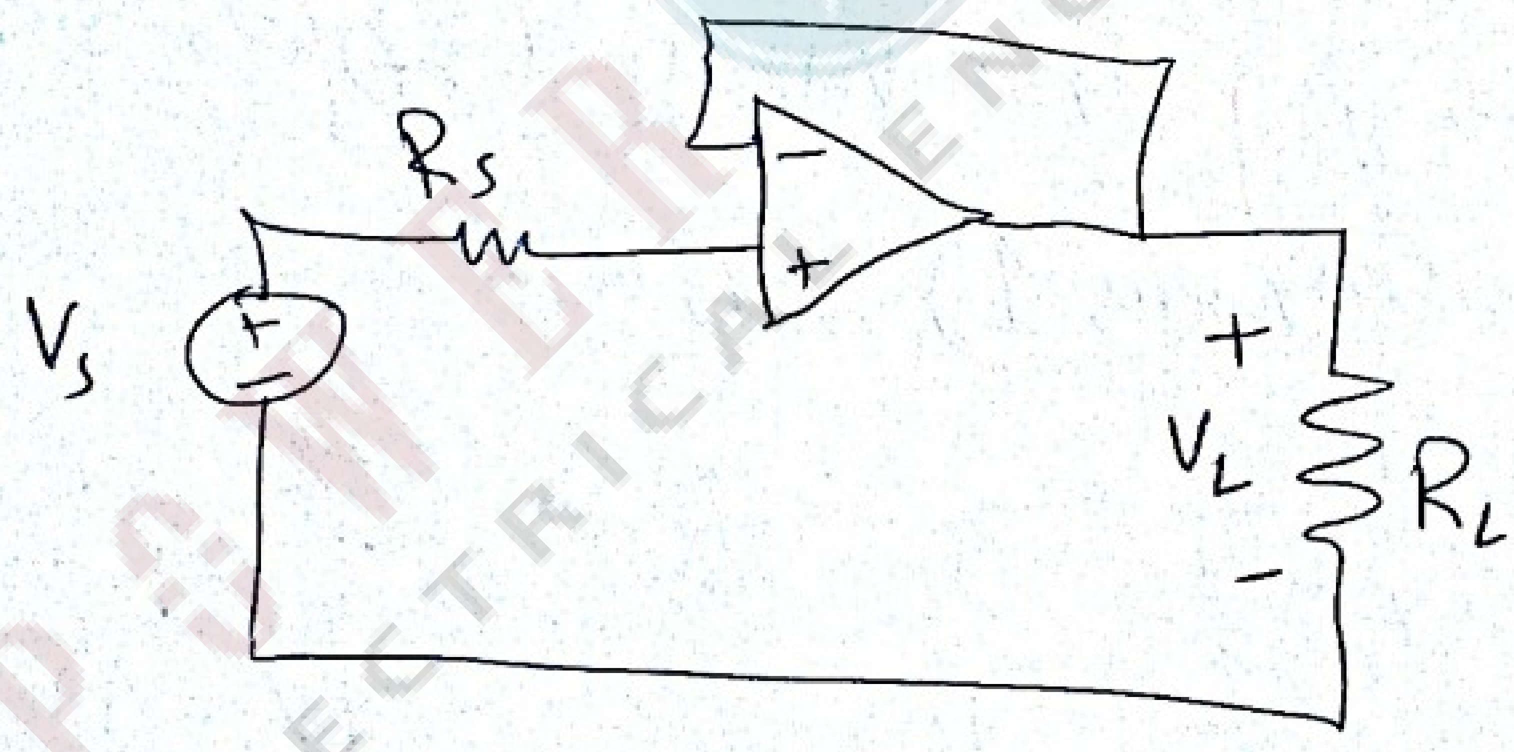



$\Rightarrow V_L = V_s \dfrac{R_L}{R_L + R_s}$

⇒ load effect Problem. #

* Ⓑ ($V_s$) is Not a fixed Voltage exactly.

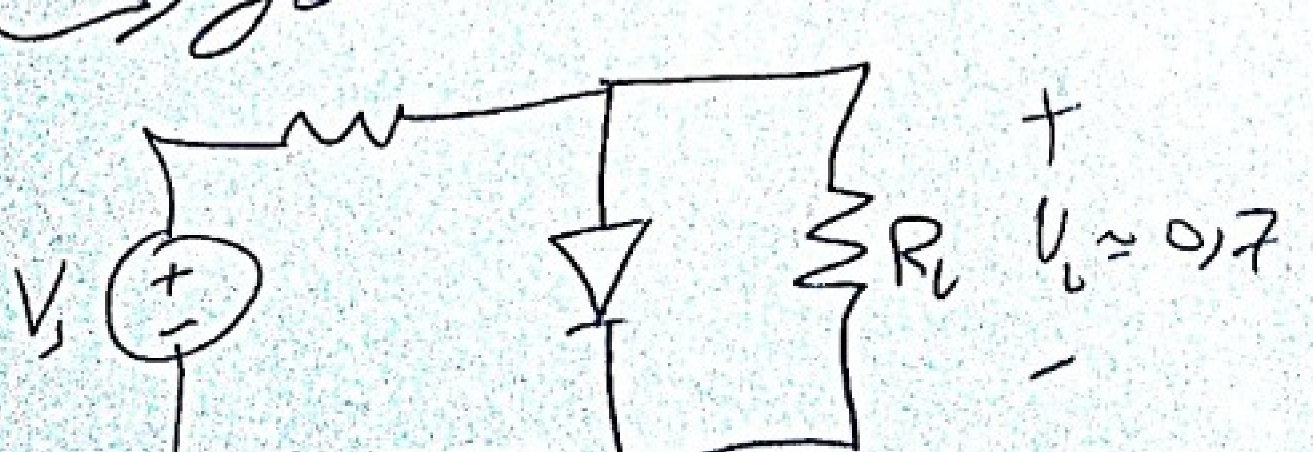
solution①
⇝ You can solve this Problem « load effect » by using the <u>Buffer</u>.

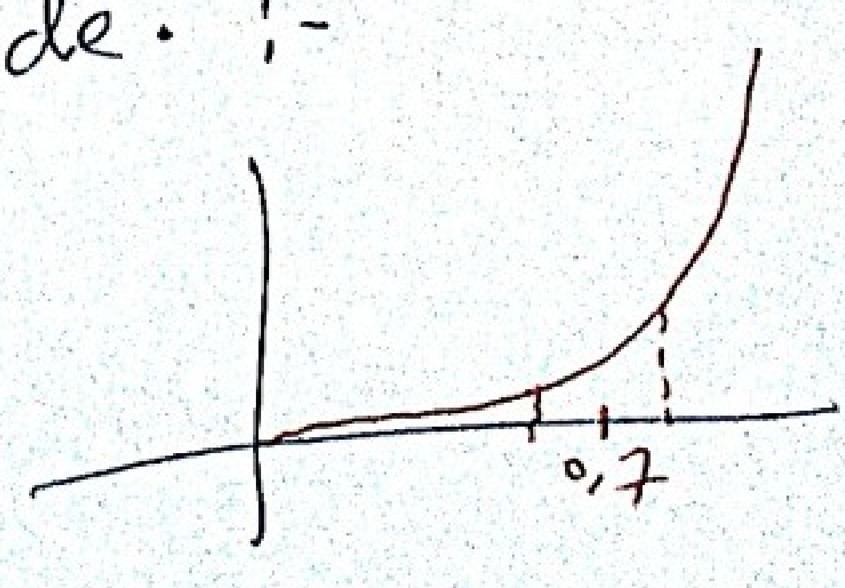



$\boxed{V_L = V_s}$ #

but we have other Problem Ⓑ it's the ($V_s$) Not <u>a fixed</u> Voltage exactly.

solution②
⇝ You can use the diode. :-



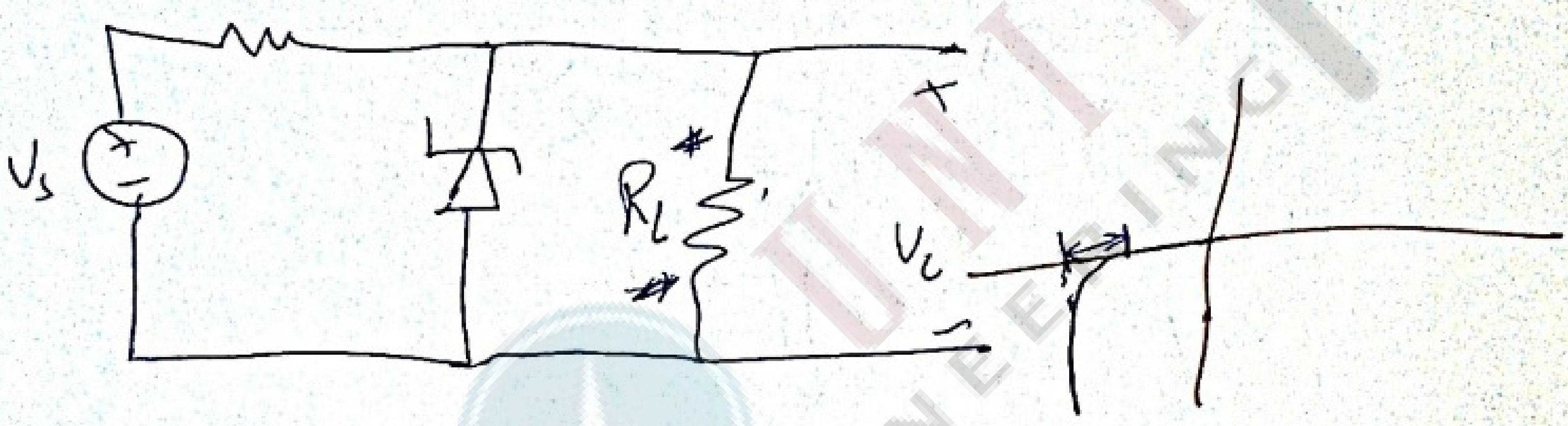



solution by using the diode we have 2 problem

(A) $V_s \nearrow \Rightarrow I_D \nearrow \Rightarrow V_D \nearrow$

(B) some time we need $V_L > 0.7$

solution *(3) $\rightarrow$ use Zenar Diode :-




Problem:-

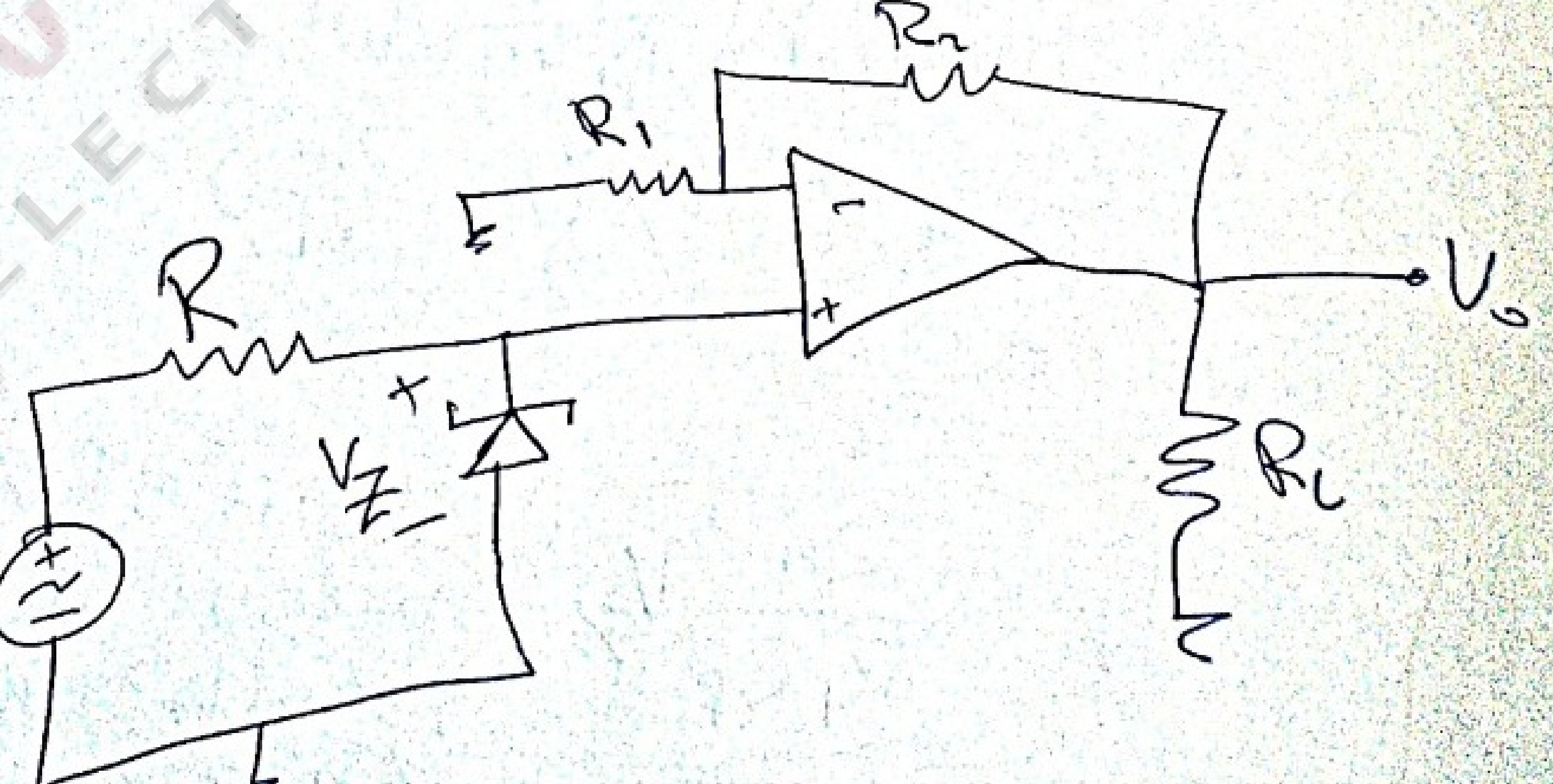
(A) $V_s \nearrow, I_Z \nearrow, V_L \nearrow$

but less than in solution *2 by the Diode.

(B) alsow some time we need $V_L > V_Z$

(C) we have the range of $R_L$ max and min.

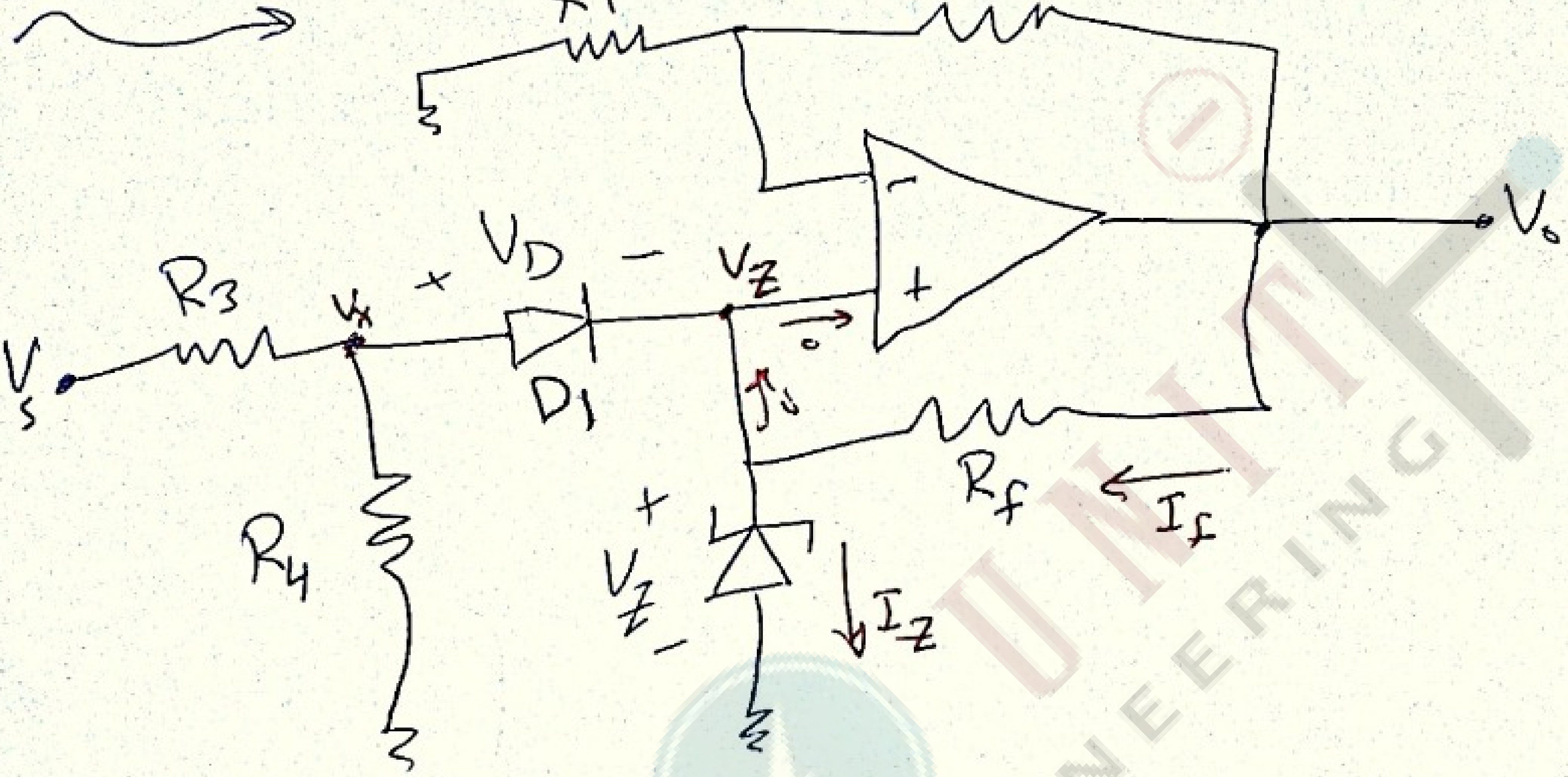
solution *(4)




$$\boxed{V_o = \left(1 + \frac{R_2}{R_1}\right) V_Z = V_L}$$ #

but in solution #4 only solve the Problem #(B) in solution #1, 2, 3

solution #5




$\Rightarrow D_1$ is on if $(V_x - V_Z) > V_\gamma$

$$V_x = V_s \times \frac{R_4}{R_3 + R_4}$$

then the voltage $V_Z$ will be generated across Zenar Diode.

$\Rightarrow$ Increase $(V_s)$ until $D_1$ is ON then tern-off $(V_s)$

$\Rightarrow D_1$ off. $\Rightarrow V_o = V_Z \left(1 + \frac{R_2}{R_1}\right)$

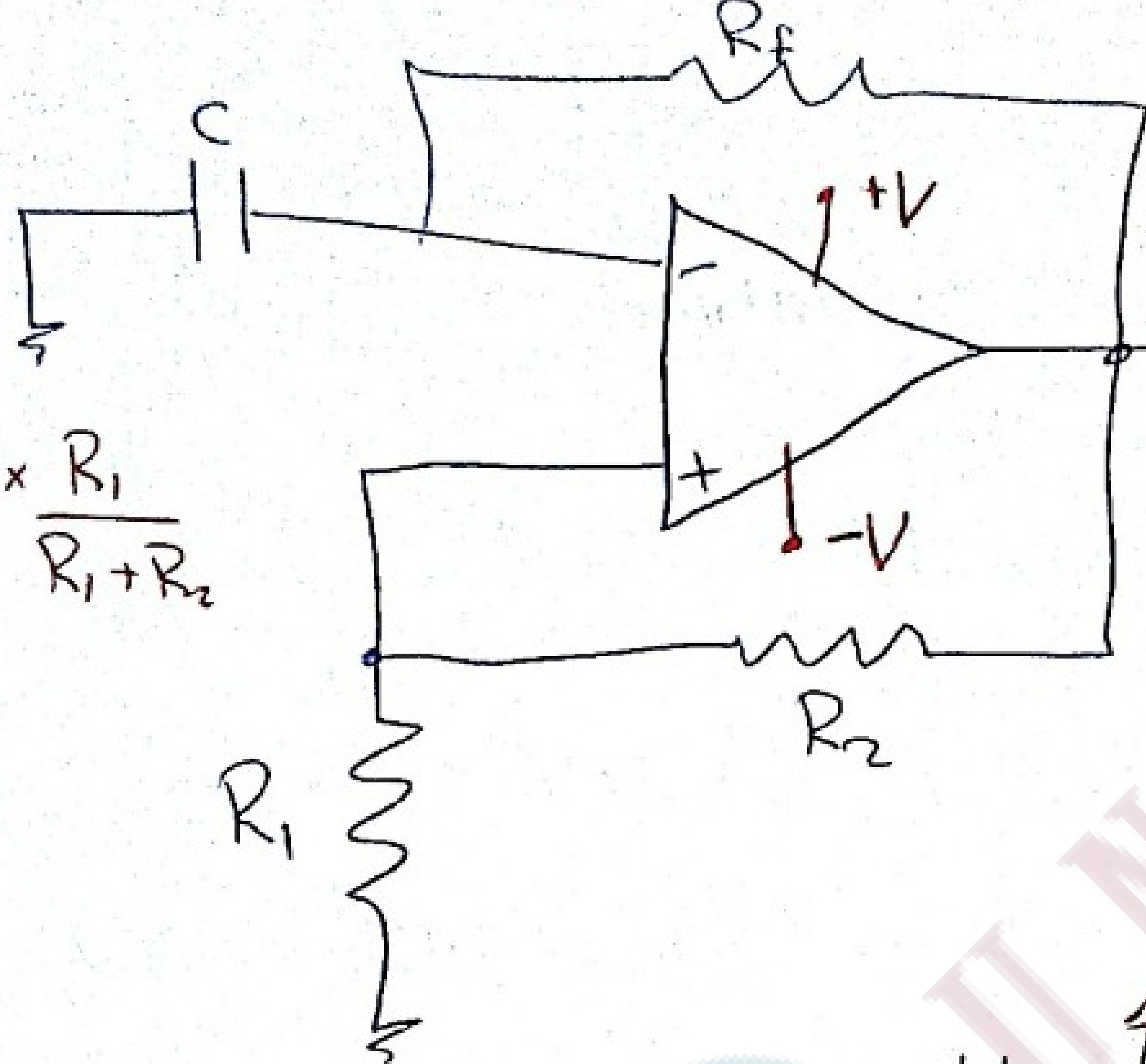
$$\Rightarrow I_f = \frac{V_o - V_Z}{R_f}$$

$$\Rightarrow \boxed{I_f = I_Z = \frac{R_2}{R_1 R_f} V_Z}$$

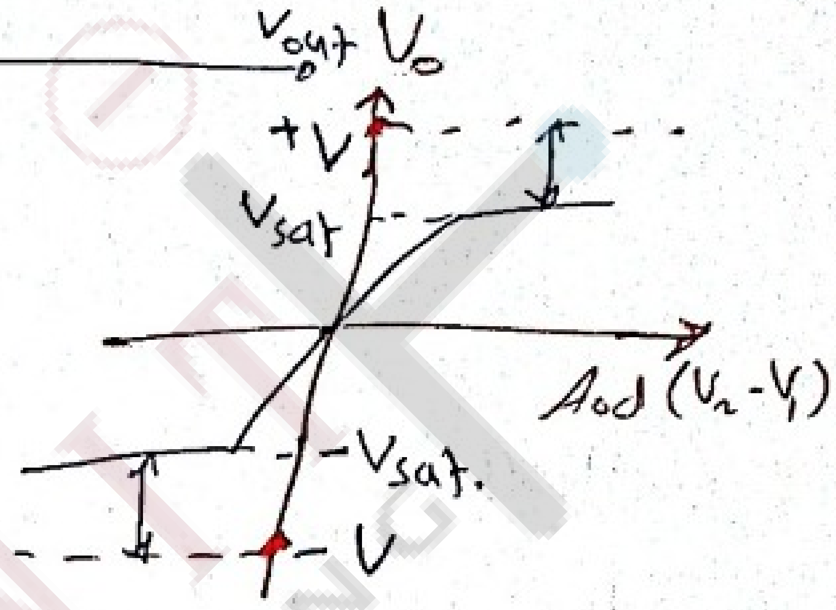
$(V_o)$ is a fixed value because it's Indep. on the $(V_I)$ and you ~~can controlled by $(V_o)$~~.

and you can control the $(V_o)$ by $R_2$ and $R_1$ and $R_f$ ------ etc.

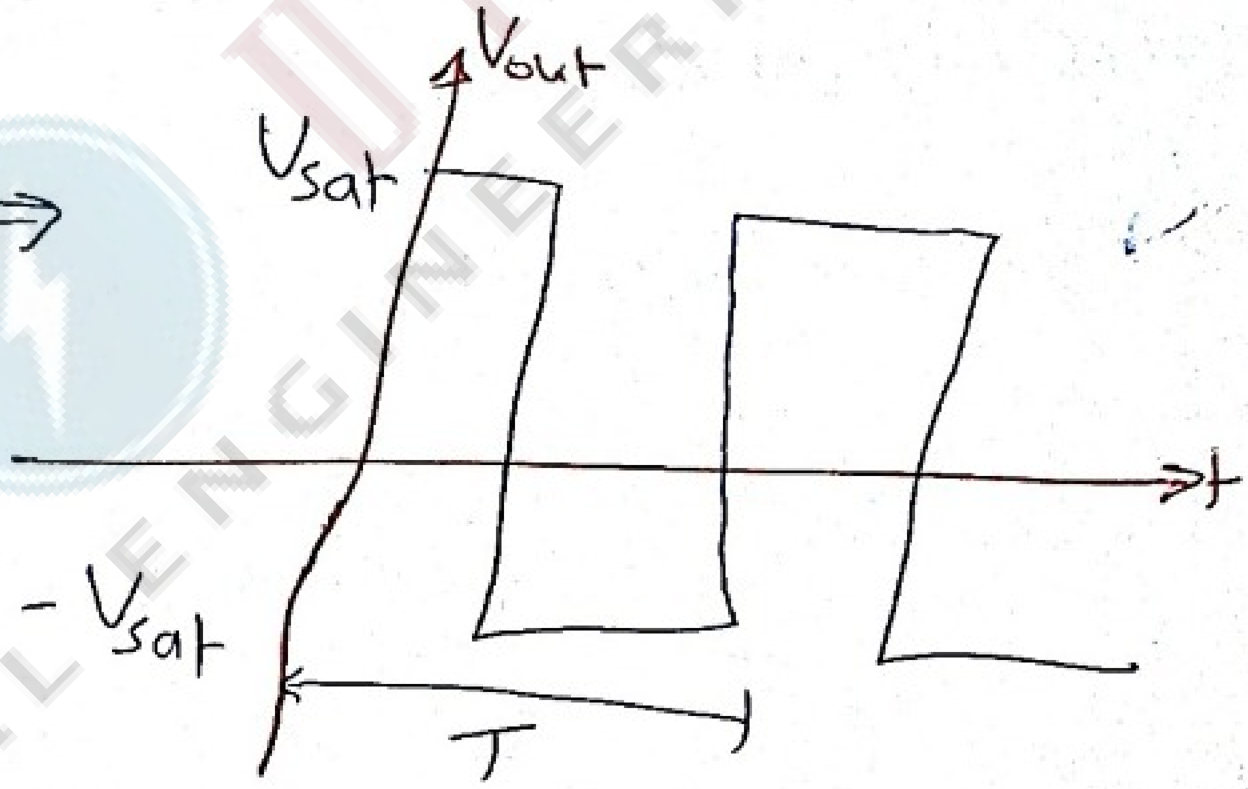
Square - wave generator




$V_i = V_o \times \frac{R_1}{R_1 + R_2}$




⇒




حفظ

$$T = 2 R_f C \ln\left(\frac{1+\lambda}{1-\lambda}\right)$$

where $\lambda = \frac{R_1}{R_1 + R_2}$

$V_o = +V_{sat}$ if $V_2 > V_1$

$V_o = -V_{sat}$ if $V_2 < V_1$

(C) is charge if $V_o > V_c$

(C) is discharge if $V_o < V_c$

# * feedback and Stability :- [illegible]

* Type of feed Back «fb» :- ① Possitive fb
② Negative fb

① +ve fb use in «oscillator».

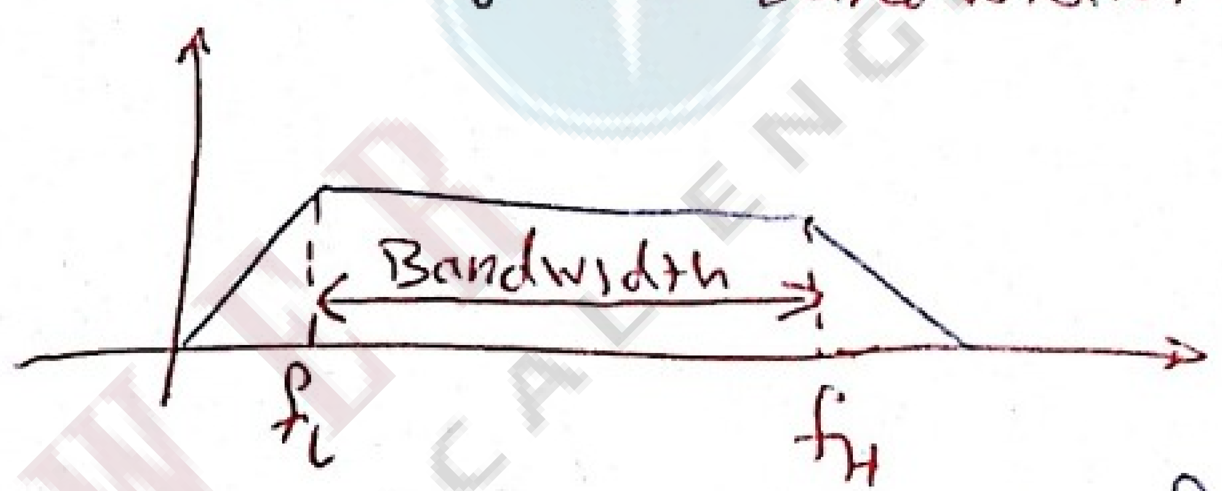
② -ve fb use in «Stability».

Now we will stady only -ve feed back.

## * Advantage of -ve feedback «-ve f.b» :-

① Stable gain :- ⇒ The gain is Insinsitive to the Transistor Parameters «$\beta$, $I_B$, $I_C$, $I_E$, $g_m$, ----etc.».

② -ve f.b increasing the Bandwidth :-




$$\text{Bandwidth} = B = f_H - f_L$$

③ -ve f.b increasing the Signal to Noise ratio :-

$$SNR = \frac{\text{Signal Power}}{\text{Noise Power}}$$

④ -ve f.b ~~reduces~~ reduces the Non-linear distortion :- whitch across due to large signal

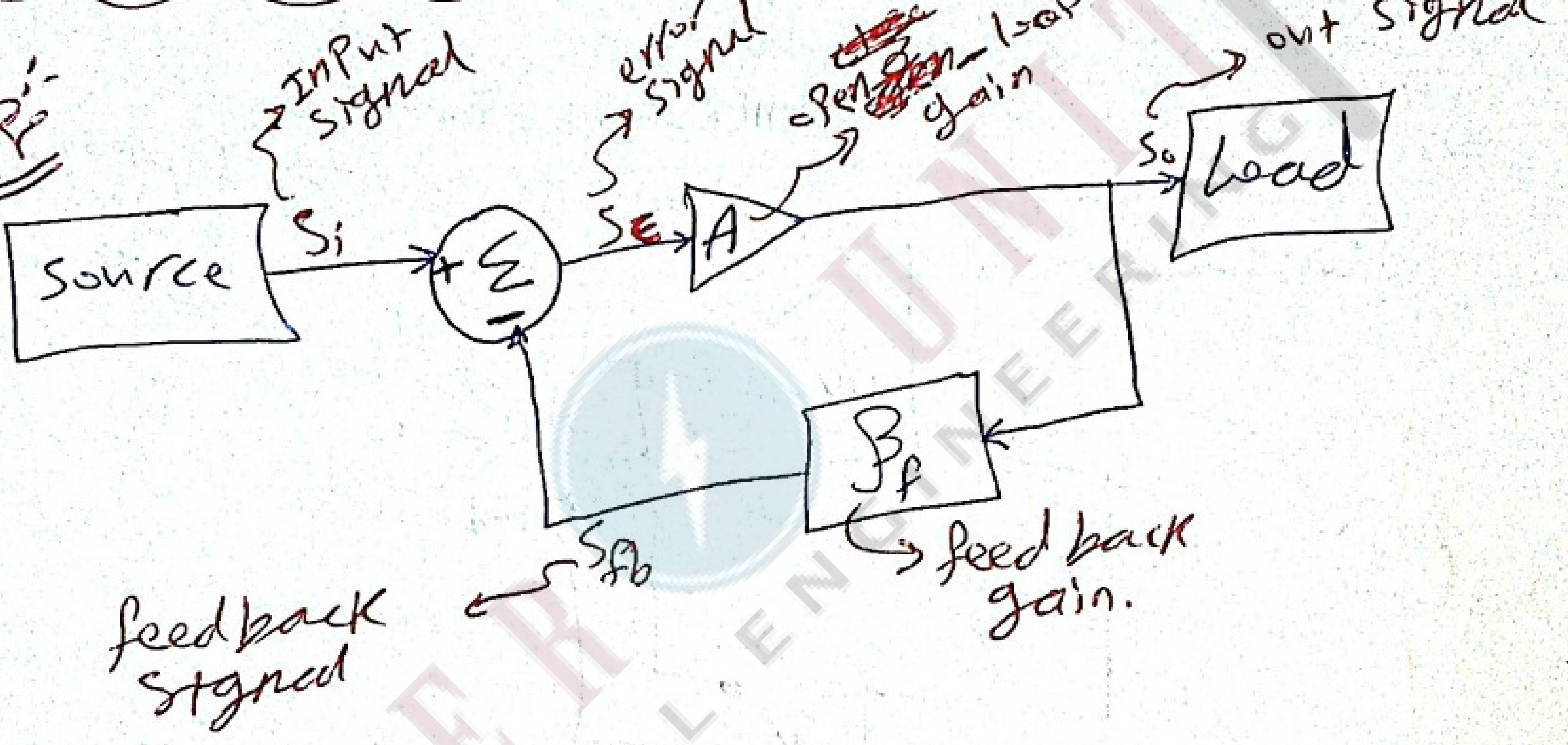
⑤ -ve f.b can control «increas OR decrease» the Input and output Impedances.

Disadvantage for -ve feedback ga

① -ve f.b reduces the gain .

② at High freq. the -ve feedback may result in unstable circuit.

Ex :-




$$\Rightarrow S_o = A S_\epsilon$$

$$S_\epsilon = S_i - S_{fb}$$

$$S_{fb} = \beta_f S_o$$

$$\Rightarrow S_o = A(S_i - \beta_f S_o) \Rightarrow S_o(1 + A\beta_f) = A S_i$$

$$\Rightarrow A_f = \frac{S_o}{S_i} = \frac{A}{1 + A\beta_f}$$

gain without feedback

gain with feedback

usually ~~the gain~~ $\beta_f A \gg 1 \Rightarrow A_f = \frac{1}{\beta_f} \Rightarrow$ stable gain

~~that~~ but the $A_f$ is low by the value $\left(\frac{1}{1+A\beta_f}\right)$

# * feedback and stability :-

* Type of feedback «fb» :- ① Possitive fb ② Negative fb

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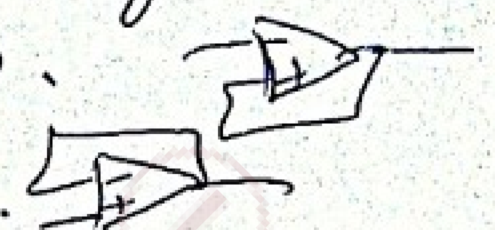

Now we will stady only -ve feedback.

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① Stable gain :- ⇒ The gain is Insinsitive to the Transistor Parameters «$\beta, I_B, I_C, I_E, g_m$, ----etc.».

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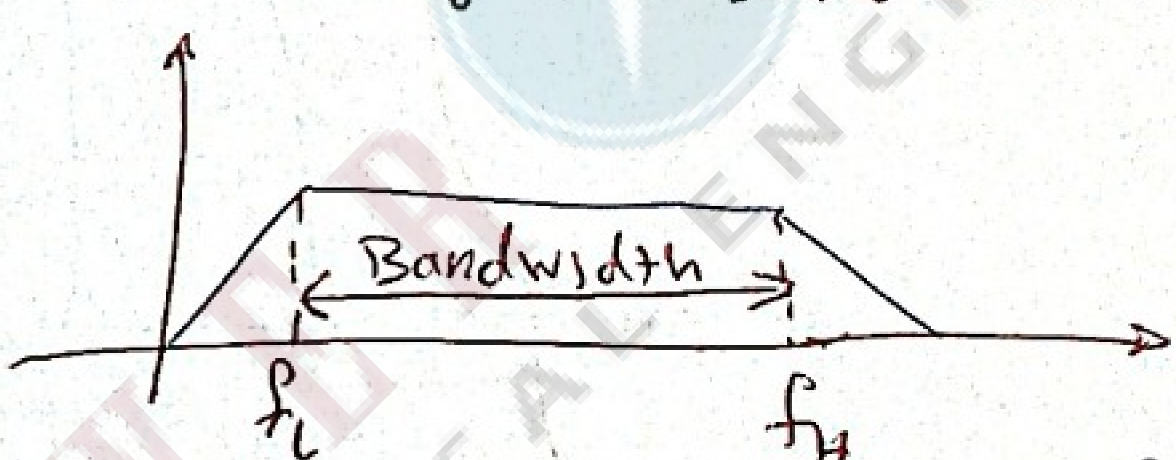


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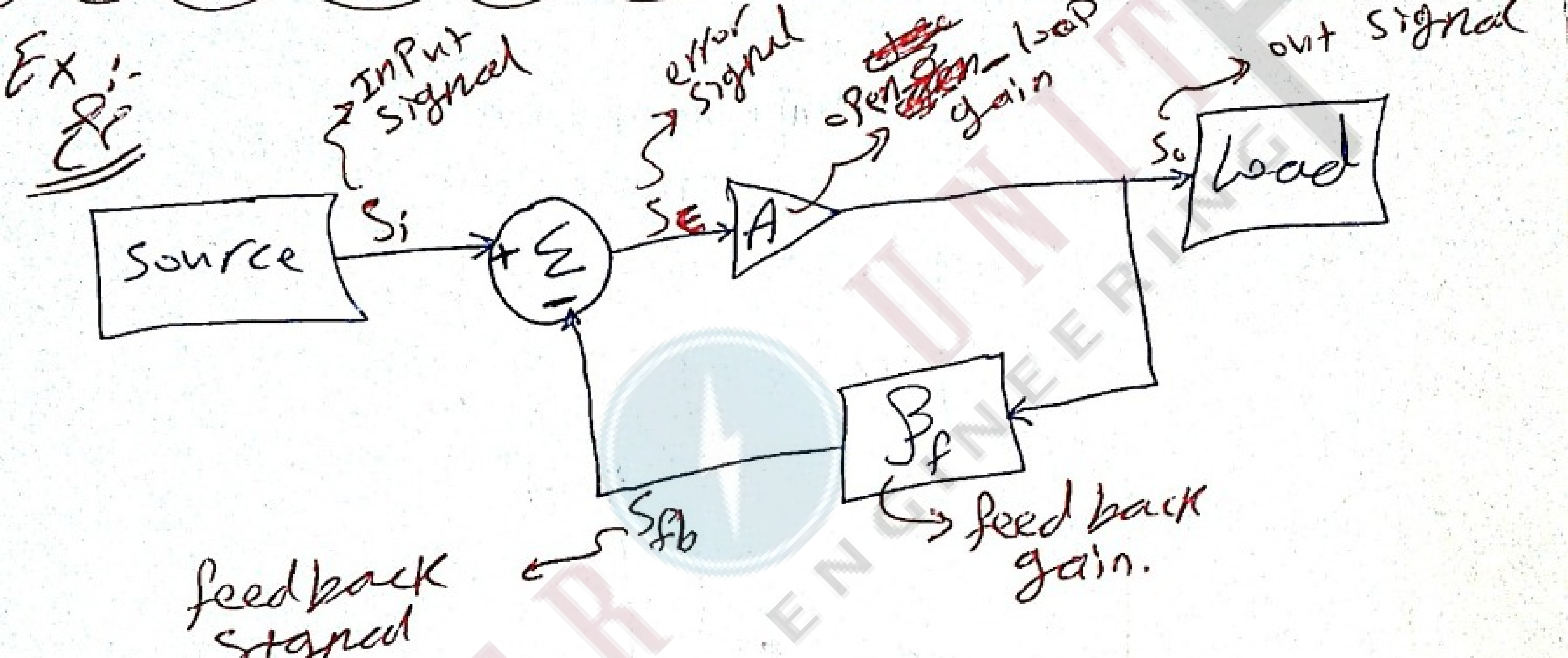


$\Rightarrow S_o = A S_\epsilon$

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$$\Rightarrow \boxed{A_f = \frac{S_o}{S_i} = \frac{A}{1 + A\beta_f}}$$

gain without feedback

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usually ~~the gain~~ $\beta_f A \gg 1 \Rightarrow A_f = \frac{1}{\beta_f} \Rightarrow$ stable gain

~~that~~ but the $A_f$ is low by the value $\left(\frac{1}{1 + A\beta_f}\right)$

gain × Bandwidth = constant.

أشكال التوصيل

* Feedback topologies « configration » فيه

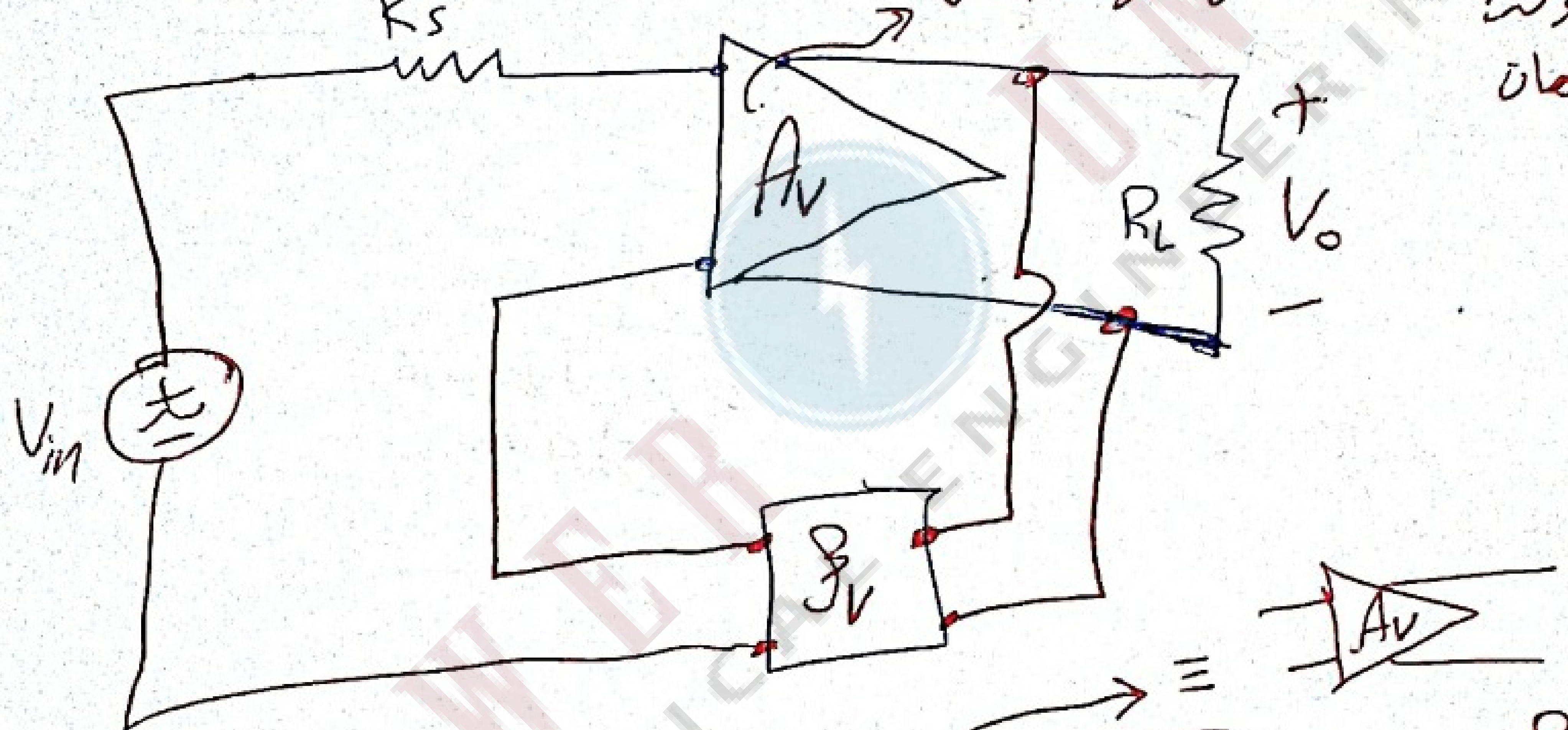
« connection between input and output »

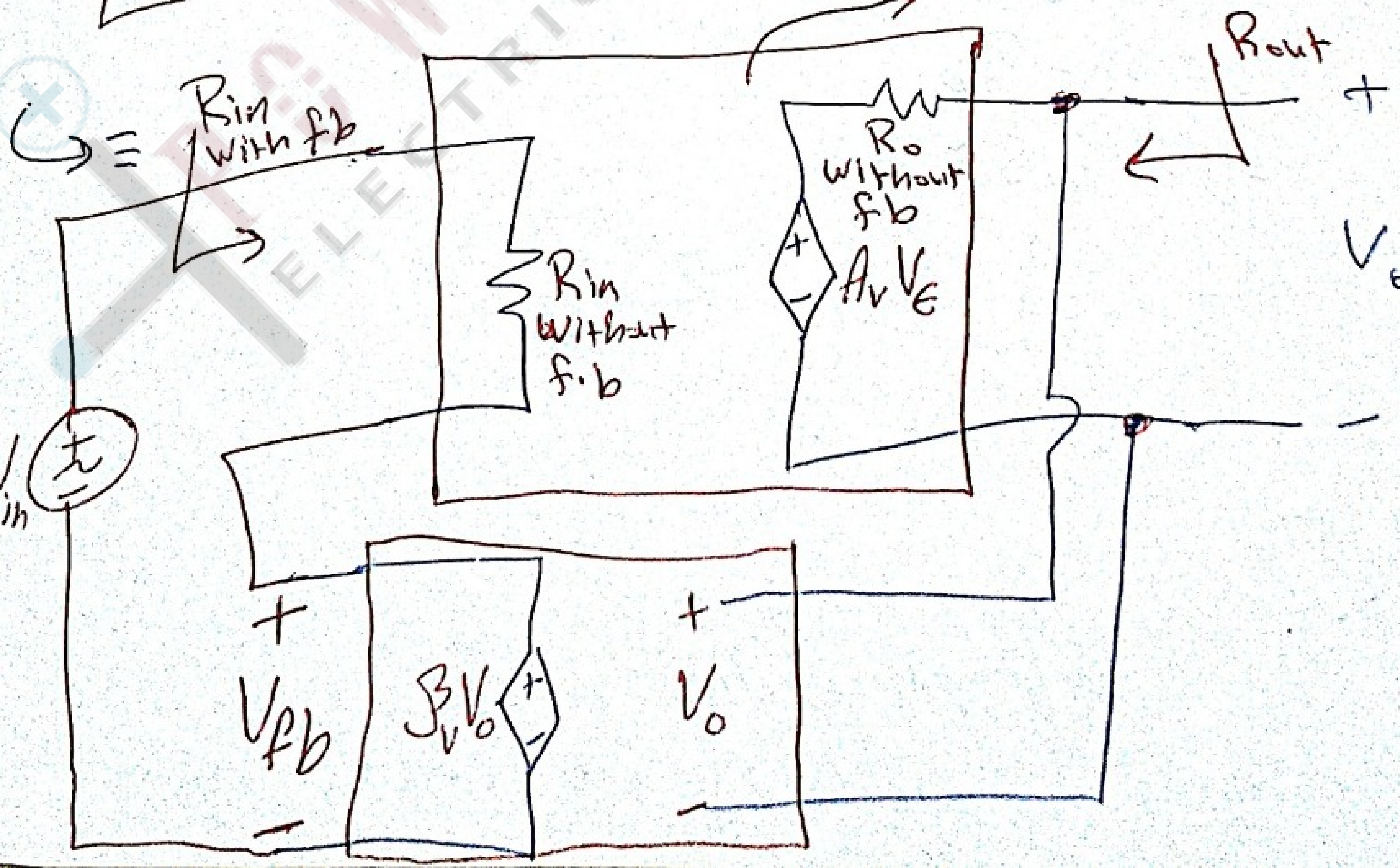
## [1] series - shunt

series → ≡ input series

shunt → ≡ output suhnt « shunt ≡ Parallel »

Voltage gain ⇒ لأنه الـ (IN) عبارة عن فولتية والـ (out) كمان فولتية.



⇒ in Series - shunt :-

① $\boxed{A_{V_{fb}} = \dfrac{A_V}{1+\beta_V A_V}}$ where :-
$A_{V_{fb}}$ :- gain with feedback
$A_V$ :- gain without feedback.

→ gain ↓ decrease with fb → factor $(1+\beta_V A_V)$

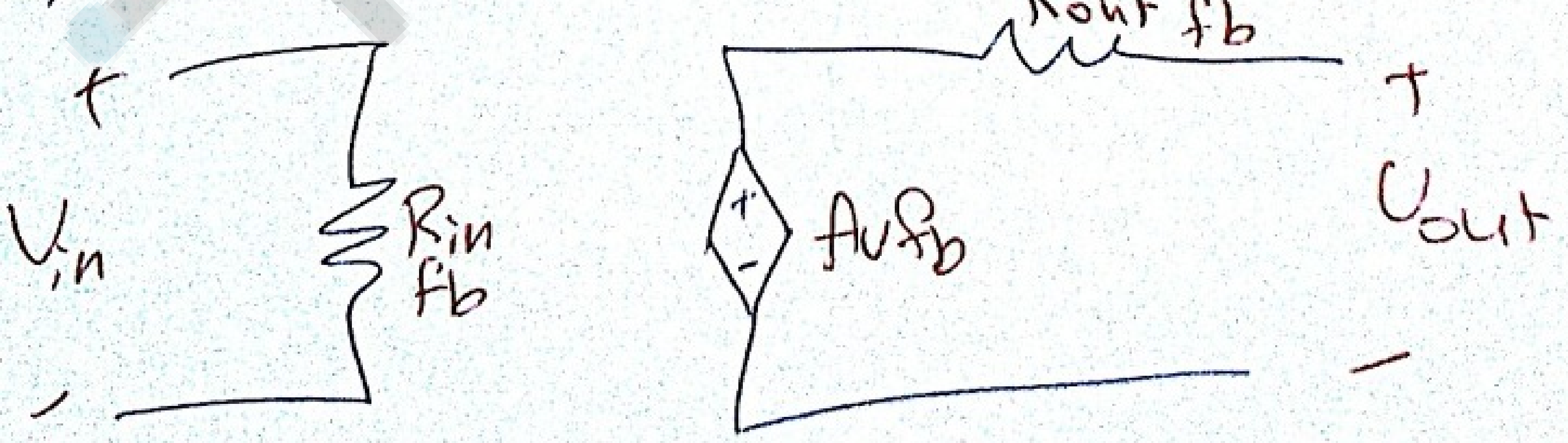
② $\boxed{R_{in_{fb}} = R_{in}(1+\beta_V A_V)}$ where
$R_{in_{fb}}$ :- Rin with feedback
$R_{in}$ :- Rin without feedback.

→ Rin ↑ increase with fb → the factor $= (1+\beta_V A_V)$

③ $\boxed{R_{out_{fb}} = \dfrac{R_{out}}{1+\beta_V A_V}}$

→ Rout ↓ decrease with fb → the factor $(1+\beta_V A_V)$

⇒ series - shunt as a two Port Network :-



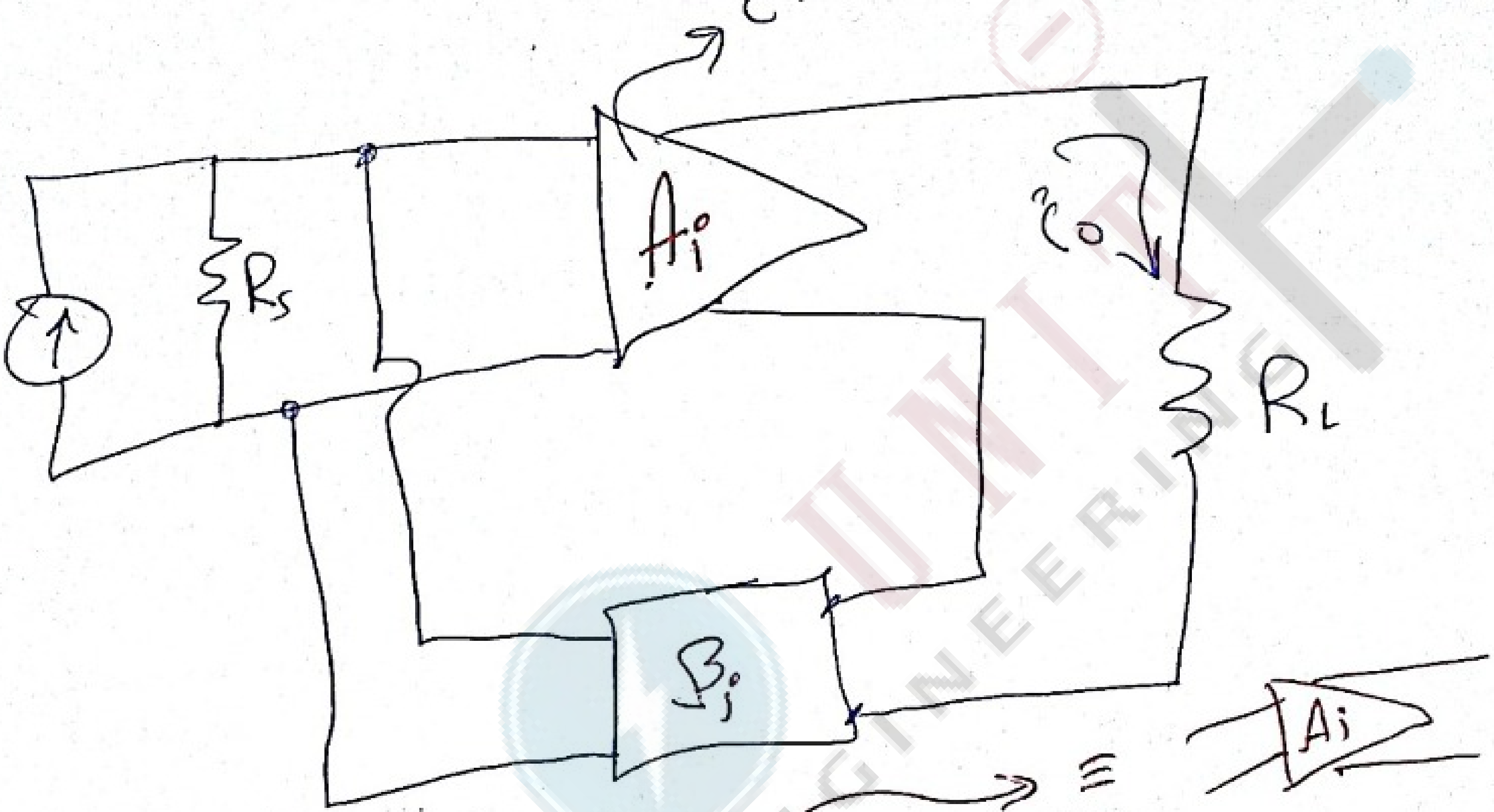

where $R_{in_{fb}}$, $R_{out_{fb}}$, $A_{V_{fb}}$ as the up equation.

[2] Shunt - series

≡ Input shunt «Parallel»

≡ output series

current gain $\frac{i_o}{i_s}$



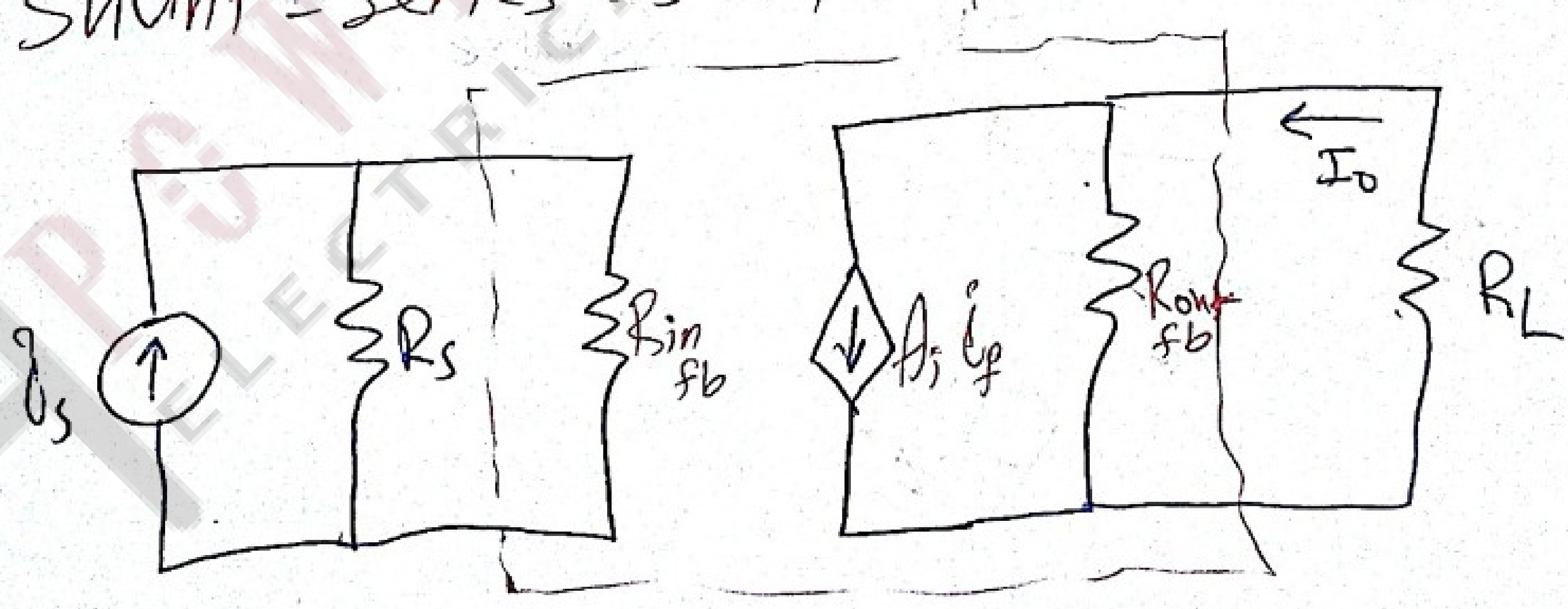

## In shunt - series

① $A_{i_{fb}} = \dfrac{A_i}{1+\beta_i A_i}$ $\Rightarrow$ current gain ~~decreased~~ with feedback will decrease by the factor $1+\beta_i A_i$

② $R_{in_{fb}} = \dfrac{R_{in}}{1+\beta_i A_i}$ $\Rightarrow$ $R_{in}$ with fb will decrease by the factor $1+\beta_i A_i$

③ $R_{out_{fb}} = R_{out}(1+\beta_i A_i)$ $\Rightarrow$ $R_{out}$ with fb will increase ↑ by a factor $1+\beta_i A_i$

⇒ Shunt - series as a two Port Network :-




where $R_{in_{fb}}$, $R_{out_{fb}}$, $A_{i_{fb}}$ as the UP equation

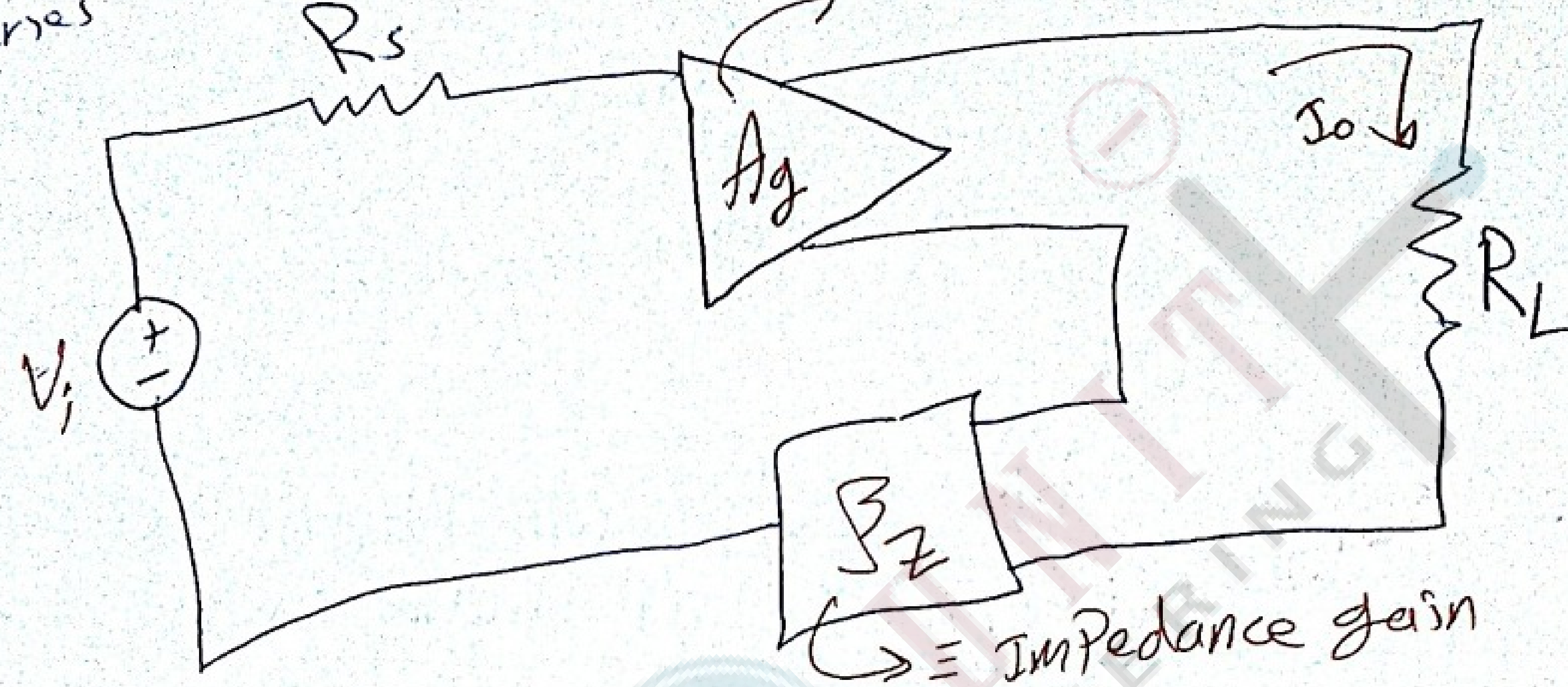
## $\boxed{3}$ series - series ده

input series

output series

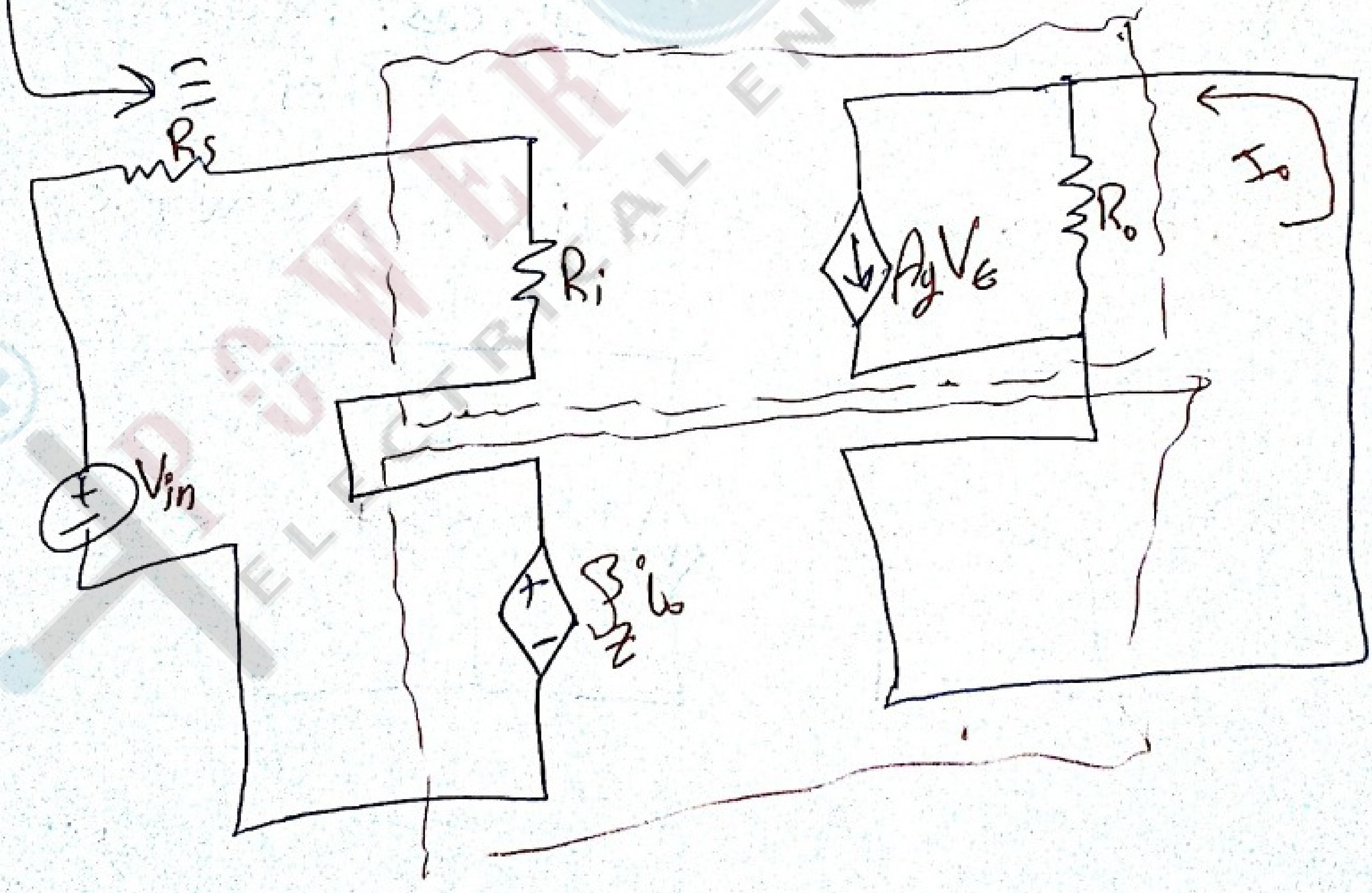
$A_g$ = conductance gain $\equiv \left(\frac{1}{R}\right) ℧$

$\boxed{A = \frac{I}{V}}$ دي




$\equiv$ Impedance gain $\equiv (R)\ \Omega$

$\left(A = \frac{V}{I}\right)$ دي



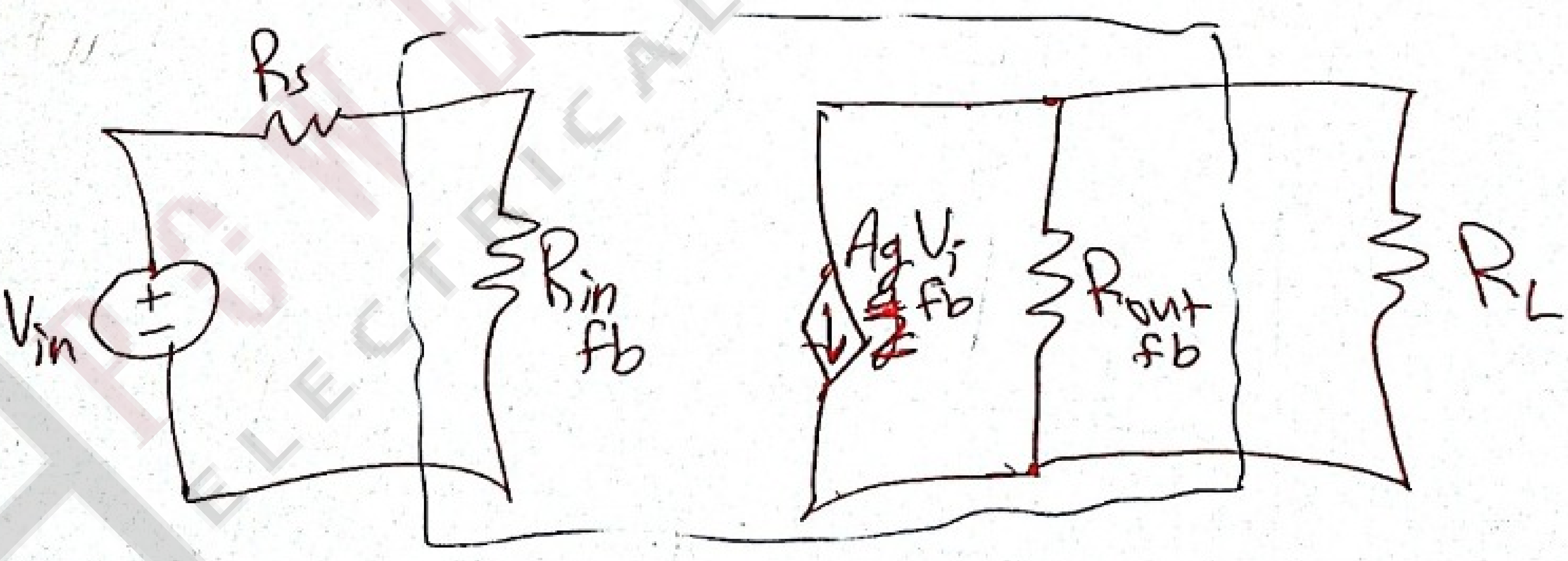
## In series - series :-

① $A_{g_{fb}} = \dfrac{A_g}{1+\beta_Z A_g}$ ⇒ gain with feed back will decrease ↓ by the factor $1+\beta_Z A_g$

② $R_{in_{fb}} = R_{in}(1+\beta_Z A_g)$ ⇒ Rin with feed back will increase ↑ by the factor $1+\beta_Z A_g$

③ $R_{out_{fb}} = R_{out}(1+\beta_Z A_g)$ ⇒ Rout with fb will increase ↑ by the factor $1+\beta_Z A_g$

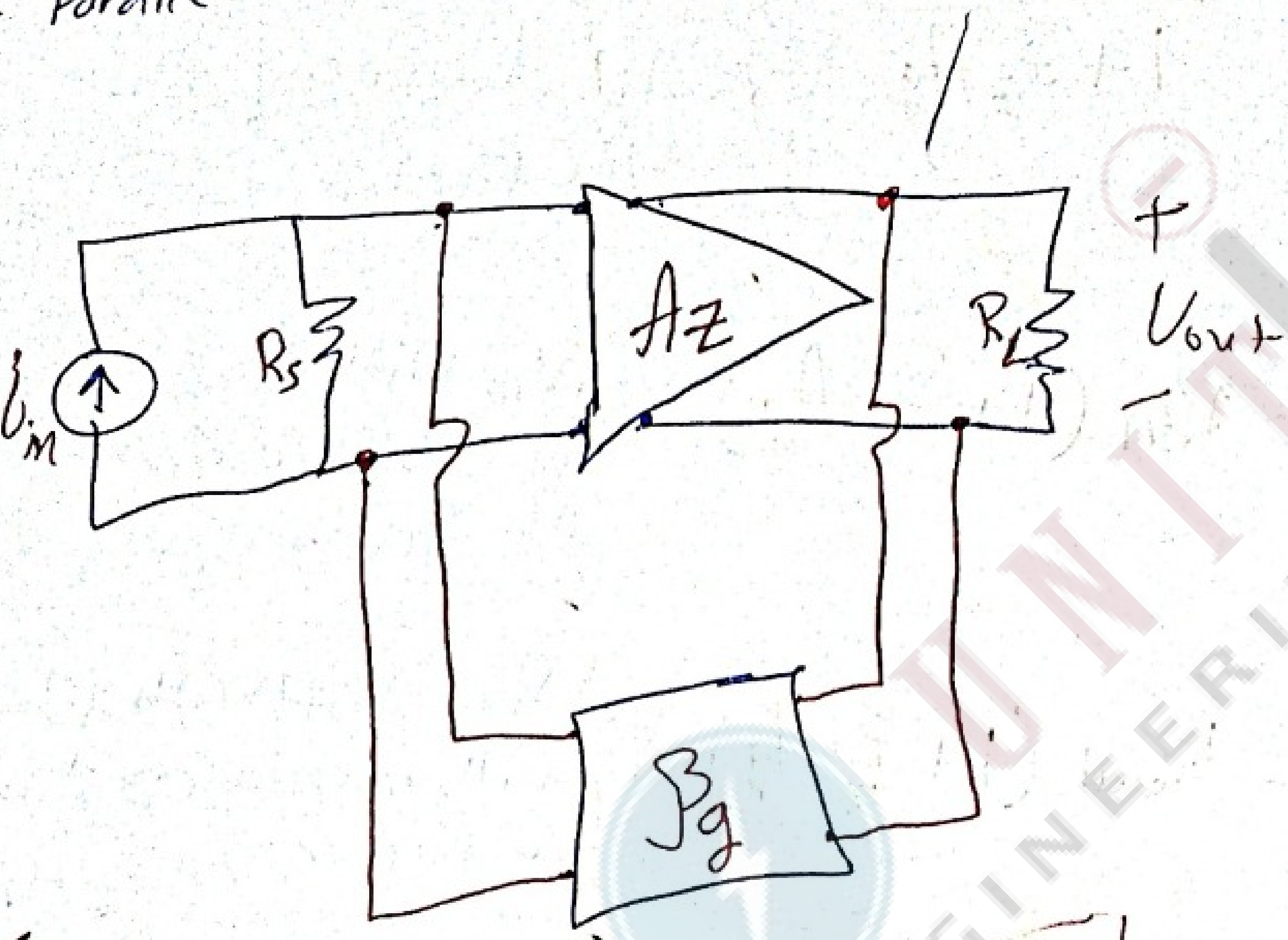
⇒ series - series as a two Port Network ;-



4 shunt - shunt :-

INPut shunt ≡ Parallel

outPut shunt ≡ Parallel

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