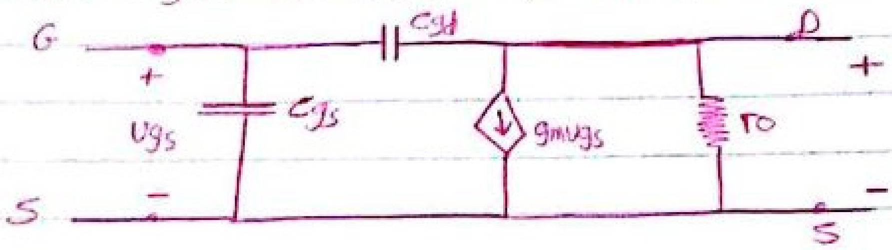
* High freq Model of MOSFET. 17/8/20

⇒ The small signal AC model of n MOSFET is:



* C_{gs} & C_{gd} are order of magnitude less than C_π & C_μ of the B

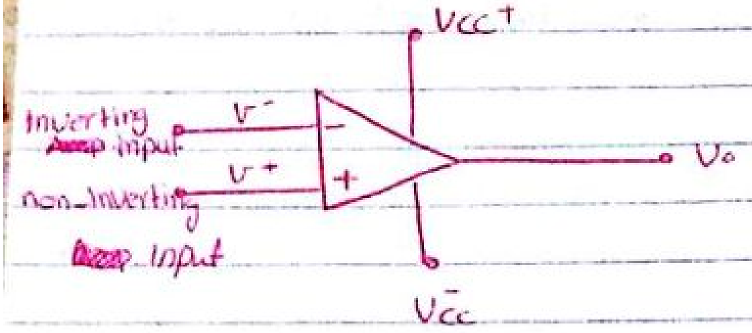
* EX: obtain the short CKT current gain for a Common-Source transistor Amplifier, then plot the Bode Diagram (See bac

* ch 9: the operational Amplifier (op_amp)

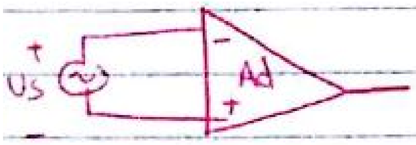
↳ The name operational Amp. stemmed from the early use of it in performing mathematical operation such as: addition, subtraction, defferentiation and Integration

* It is a 2-input, 1-output device

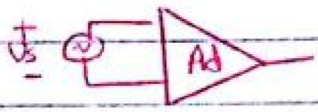
$V_o = A_d(V^+ - V^-)$, $A_d > 0$



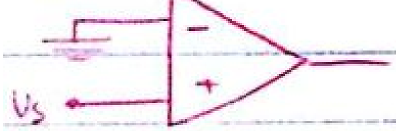
* EX:



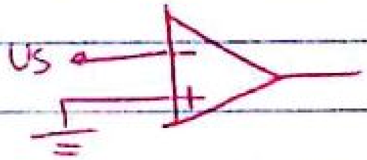
$V_o = A_d . V_s$



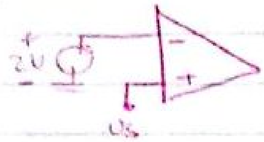
$V_o = A_d(-V_s)$
$= -A_d V_s$



$V_o = A_d(V_s - 0)$
$= A_d V_s$

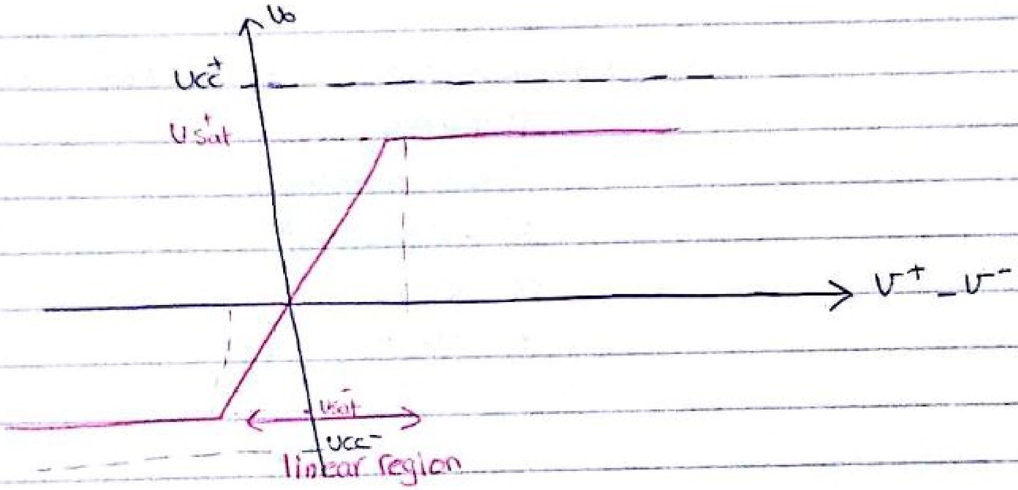


$V_o = -A_d V_s$



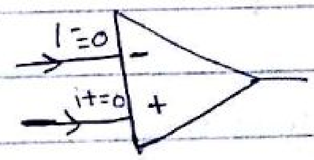
$U_o = A_d (U_s - 2)$

$U_o =$ undetermined

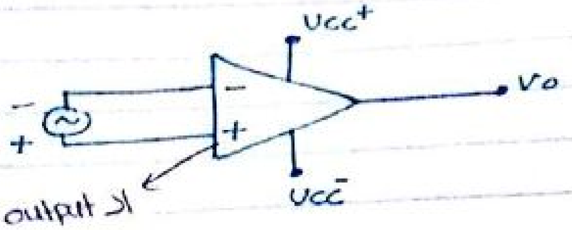


* Ideal characteristics of an op-amp:

1) It has very high voltage gain, $A_d = \infty$.
2) " " " " Input Resistance $R_i \approx \infty \ \Omega$
3) " " " low output " $R_o \approx 0 \ \Omega$
4) The Input currents i^+ & i^- are considered 0.
5) $V^+ - V^- = 0$.



2018/2017.

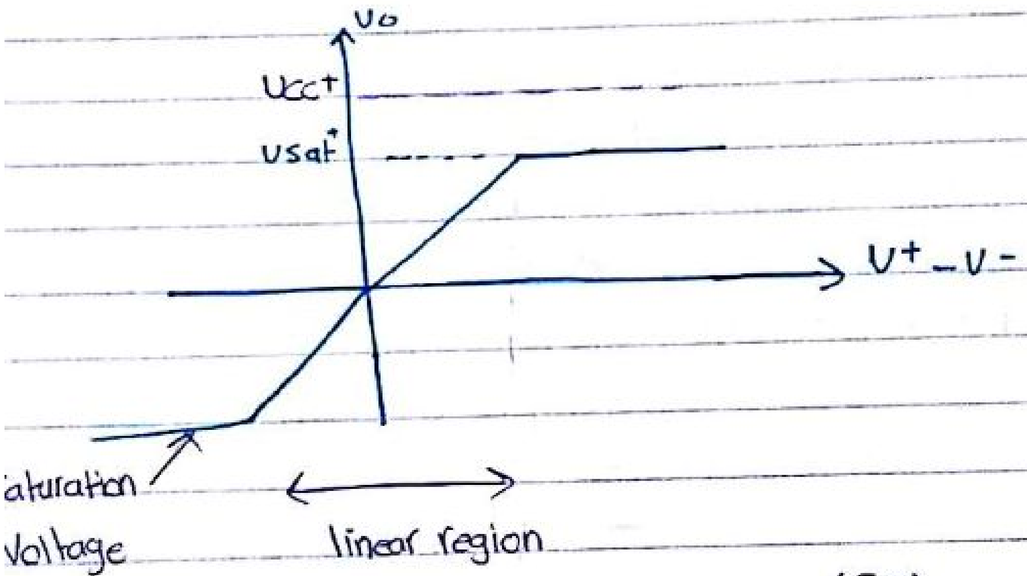


$$\boxed{V_o = A_d (V^+ - V^-) = A_d V_s}$$ * علاقة ال Amplifier

*أي op-Amp إله على الأقل 5 مداخل :

① Inverting
② non inverting
③ output Vo
④ Vcc+
⑤ Vcc-

*أي Amplifier فيها علاقة I/p مع o/p هي linear .

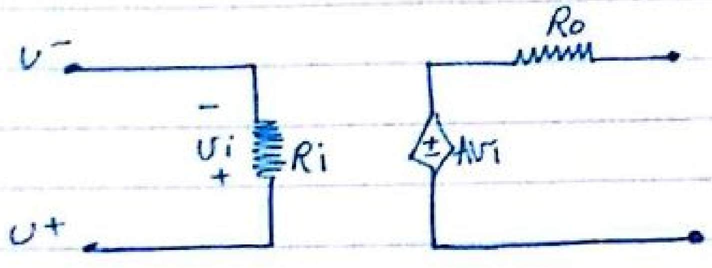


*op-amp → linear regi

* Ad → +ve ≈ 10^5

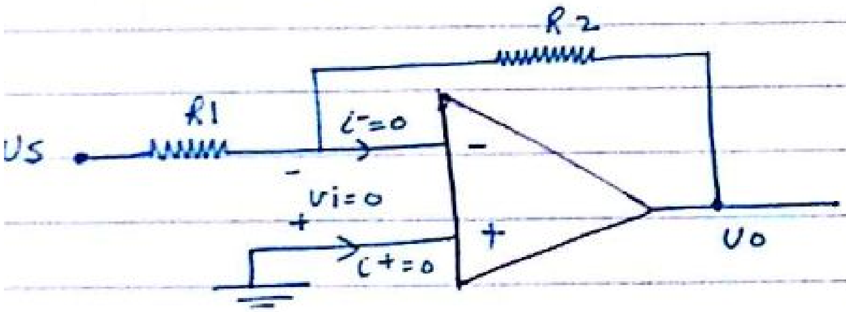
* op- Amp CKT :>

↳ The Relationships are obtained using the ideal-op amp charecterstics.



(Practical op-amp model)

* The Inverting Amplifier :>

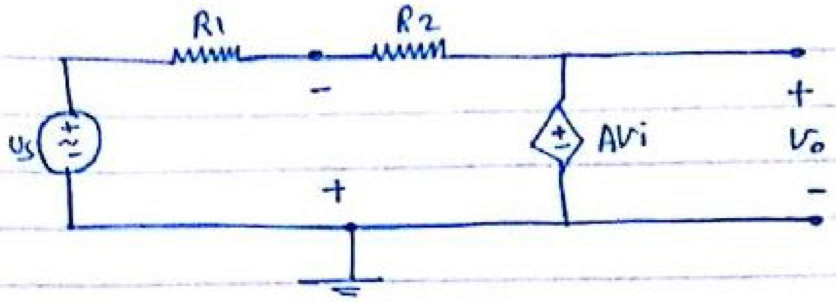


ال Vcc دائماً موجودة بس ما بنرسمها

$V^+ - V^- = 0$ → stick then return

$I^- = I^+ = 0$

دائماً بنكتبهم

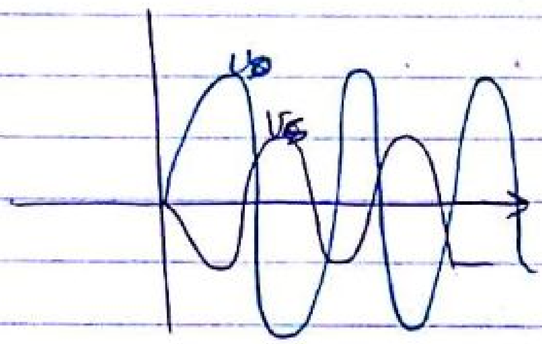


* KCl @ Inverting node :

$$\frac{U_s - \cancel{U^-}^{\,0}}{R_1} = \cancel{I}^{\,0} + \frac{\cancel{U^-}^{\,0} - U_o}{R_2}$$

$$\boxed{\frac{V_o}{U_s} = \frac{-R_2}{R_1}}$$ *

_ Uo
_ Us

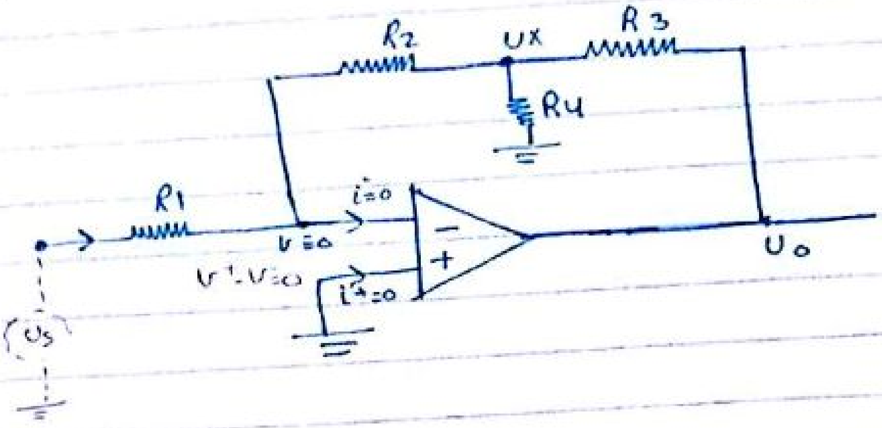


* Inverting ⟶ 180° phase shift
(معكوس الإشارة)

* a price paid for this magic configuration is that the input Resistance of the over all Amplifier cKT is know lowered to the value of R1.

21/8/2017

* The Network Amplifier



* Dis :
- Trouble shooting
- الوزن والحجم والسعر و المتغير اكثر.

$$\frac{U_s}{R_1} = 0 + \frac{0 - U_x}{R_2} \Rightarrow U_x = \frac{-R_2}{R_1} U_s$$

$$\frac{-U_x}{R_2} = \frac{U_x}{R_4} + \frac{U_x - U_o}{R_3}$$

$$\frac{U_o}{R_3} = \left[\frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4}\right] U_x$$

$$\frac{U_o}{R_3} = \frac{-R_2}{R_1}\left[\frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4}\right] U_s$$

$$\left[\frac{U_o}{U_s} = \frac{-R_2}{R_1}\left[1 + \frac{R_3}{R_2} + \frac{R_3}{R_4}\right]\right]$$

* gain

* الحاجة الى T-Network بتعطي مرونة أكثر ولتسمح انه نزيد R_1 حتى نزيد Input_Resistance وبالتالي ما يقل ال gain بسبب وجود الحد $\left[1+\frac{R_3}{R_2}+\frac{R_3}{R_4}\right]$

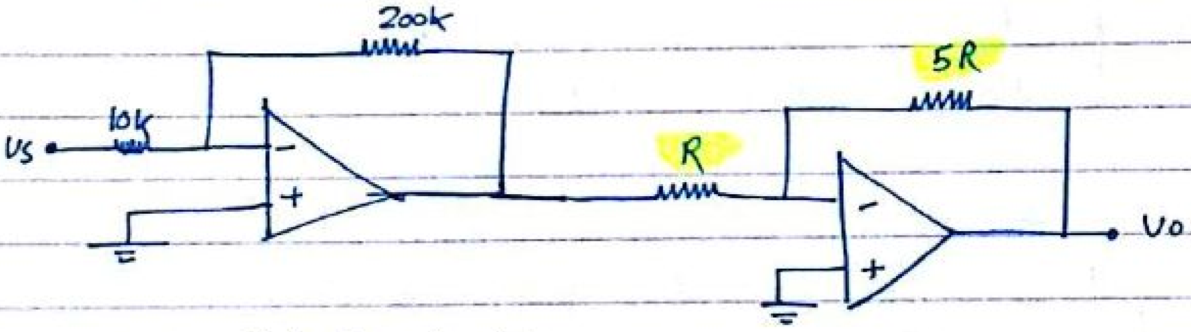
⟹ This CKT permits the use of a high value for R_1 to increase the input resistance without the specific at a lower gain.

* The over all gain is raised through the multiply factor

$$\left[1+\frac{R_3}{R_2}+\frac{R_3}{R_4}\right]$$

* EX: Design an Amplifier CKT at gain = +100.

→ sol: using 2 Amplifiers in cascade.

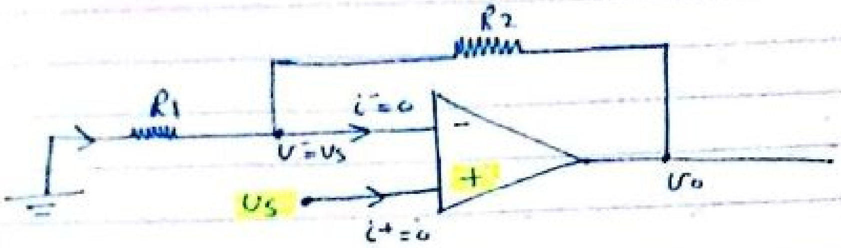


قيمة R حسب Application

$V_o = -20 \times -5 \times V_s = 100 V_s$

* DisAdvantage: using 2 op Amps $\xrightarrow{\text{الحل}}$ non Inverting.

* The Non-Inverting Amplifier :-



$v^+ - v^- = 0$

$$\frac{0 - v_s}{R_1} = 0 + \frac{v_s - v_o}{R_2}$$

$$\frac{v_o}{R_2} = \left[\frac{1}{R_1} + \frac{1}{R_2}\right] v_s \quad \Rightarrow \quad * \boxed{\frac{v_o}{v_s} = \left[1 + \frac{R_2}{R_1}\right] = \frac{R_1 + R_2}{R_1}}$$

ما في inversion (ـالها) تبقى الإشارة كما هي .

ـ gain زاد بمقدار 1 فقط

* Advantages:

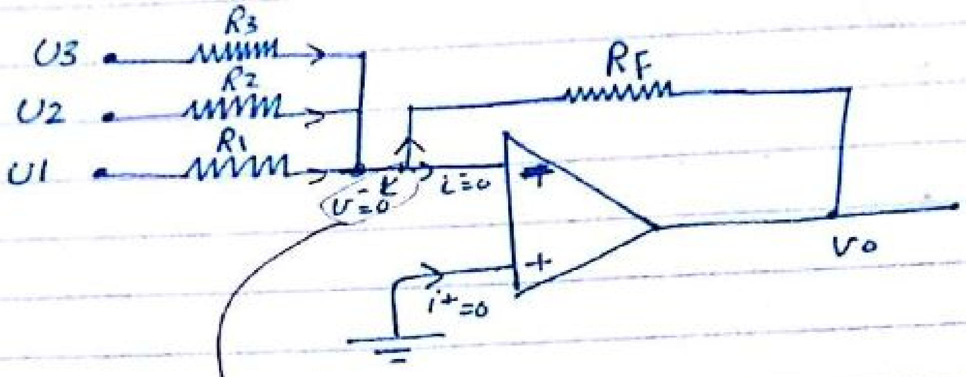
1. i.e: No sign inversion
2. It has very high Input Resistance
3. Very low output Resistance

* 2- additional advantages for the non-inverting Amp: ② & ③ -

⟹ making it an Ideal Voltage Amplifier

*EX : الإثبات مهم.

* The Summing Amplifier :



$v^+ - v^- = 0$

@ virtual ground

i.e: having the same Voltage ov, yet not physically connected.

↓

hence, the name is virtually ground.

* It can be show that:

$$* \quad U_o = -\left[\frac{R_f}{R_1} U_1 + \frac{R_f}{R_2} U_2 + \frac{R_f}{R_3} U_3\right]$$

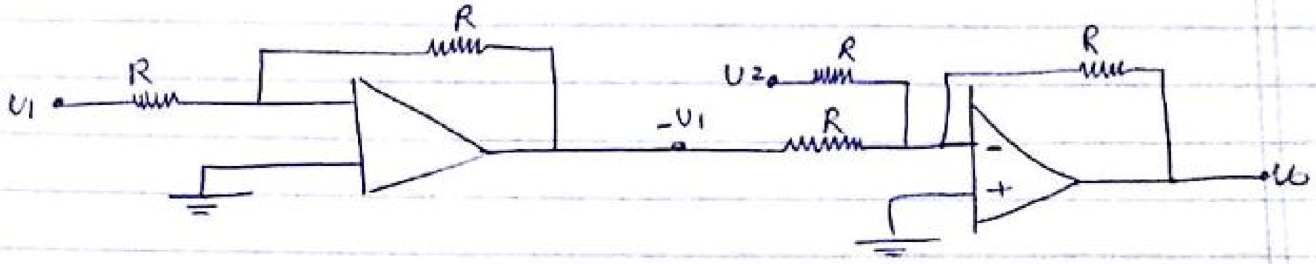
↓

علاقة جمع hence, the name (Summing Amp or Adding Amp)

(بجمعهم وبجمعهم مش بس بجمعهم).

* EX: Design a ckt to get $U_1 - U_2$.

$$U_1 - U_2 = -(-U_1 + U_2)$$

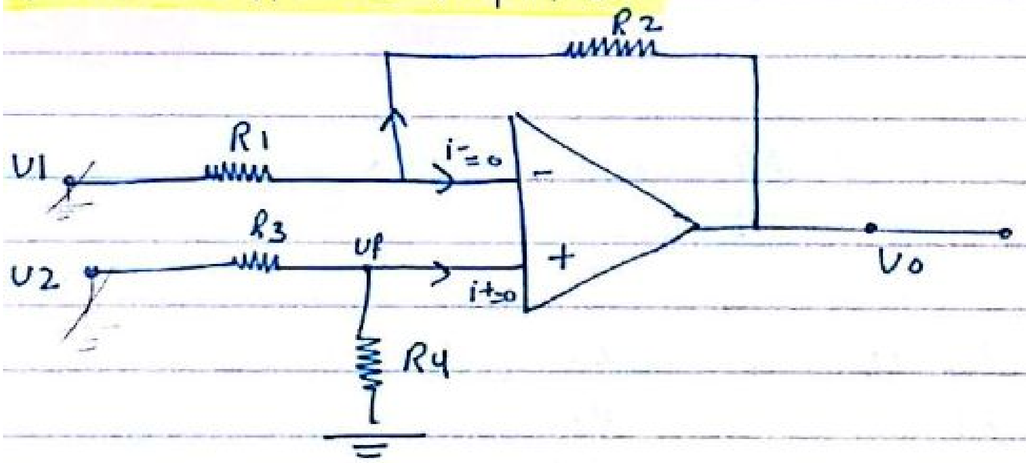


$$U_0 = -[-U_1 + U_2] = U_1 - U_2 \quad ✓$$

*Dis: The use of 2 op-amps → delay, نهاية وزن وسعر وتكلفة Troubleshooting,

↓ sol:

* The Difference Amplifier



$$U^+ - U^- = 0$$

$$U^+ = \frac{R_4}{R_4 + R_3} U_2$$

→

* Using super position : (Kill all signals except one of them):

① Kill U_1 $\longrightarrow$ Non Inverting

$$U_o = \left(1 + \frac{R_2}{R_1}\right) \frac{R_4}{R_4 + R_3} U_2$$

② Kill U_2 $\longrightarrow$ Inverting

$$U_o = -\frac{R_2}{R_1} U_1$$

$\Rightarrow$ Total:

$$U_o = \left(1 + \frac{R_2}{R_1}\right) \frac{R_4}{R_4 + R_3} \cdot U_2 + \frac{-R_2}{R_1} U_1 .$$

$$= \left(\frac{R_1 + R_2}{R_1}\right) \left(\frac{R_4}{R_4 + R_3}\right) U_2 + \frac{-R_2}{R_1} U_1$$

$\rightarrow$ If $R_1 + R_2 = R_3 + R_4$ & $\frac{R_4}{R_4}$ $R_2 = R_4$ & $R_1 = R_3$.

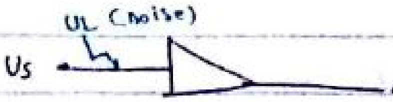
$$U_o = \frac{R_4}{R_1} U_2 - \frac{R_2}{R_1} U_1 = \frac{R_2}{R_1} (U_2 - U_1)$$ $\rightarrow$ بطرح وبكبر

اذا مابدي أكبر

بختار $R_2 = R_1$

22/8/2017

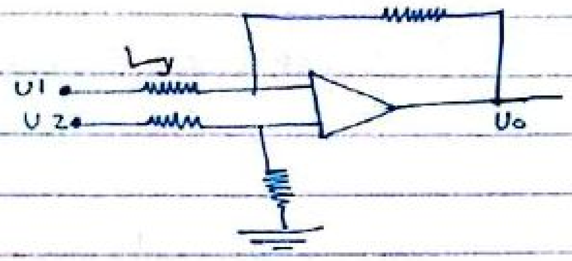
* An Advantage of a difference Amplifier is it's ability to cancel Common-mode noise signals



$V_o = A(V_s + V_L)$

بتكون الـ input والـ noise معاً.

⇒ Common-mode: مشتركة signal → يعني الـ noise بتؤثر على الـ V1 و V2 معاً



Vn: noise Vol

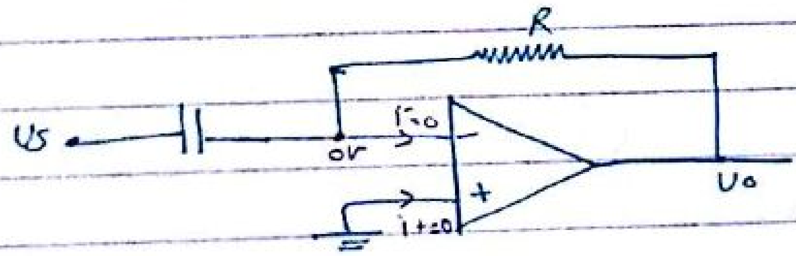
* let $V_1 = V_{S1} + V_n$

$V_2 = V_{S2} + V_n$

$$V_o = \frac{R_2}{R_1}\left(V_{S2} + \cancel{V_n} - V_{S1} - \cancel{V_n}\right) = \frac{R_2}{R_1}\left(V_{S2} - V_{S1}\right)$$

بالـ difference Amp بتكون الـ noise للأولى والثانية لكن بتوخذ الفرق ← بلغوا بعض ← عشان هيك تعتبر AdV

* The Differentiator circuit (p652)



$V^+ - V^- = 0$

(67)

Scanned by CamScanner

⟹ Using KCL:

$$C\frac{d}{dt}C(Vs-0)=0+\frac{(0-Vo)}{R}$$

$$C\frac{dVs}{dt}=-\frac{Vo}{R} \Rightarrow Vo=-RC\frac{dVs}{dt}$$

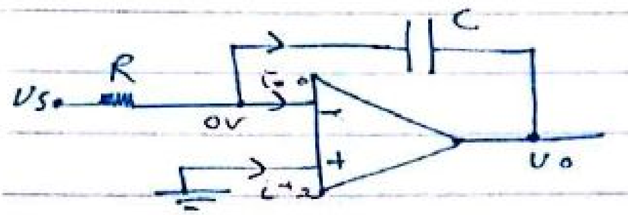
$$\left[Vo=-RC\frac{d}{dt}Vs \right]$$

RC هو مقدار Amplification، و السالب هو Inversion .

فيتم C غالباً في μ أو أقل .

* The Integrator circuit:

$V^+ - Vs^- = 0$



$$\frac{Vs-0}{R}=0+C\frac{d}{dt}(0-Vo)$$

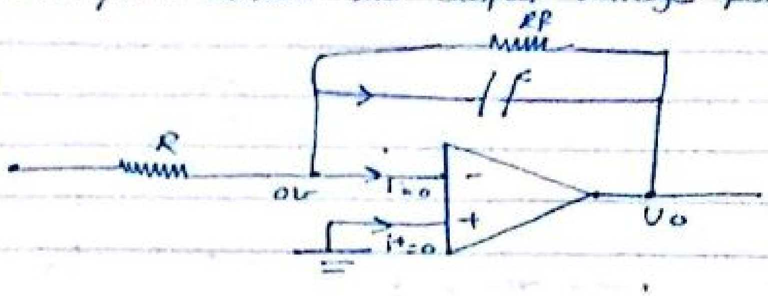
$$\frac{-1}{RC}Vs=\frac{d}{dt}Vo \Rightarrow \left[\frac{-1}{RC}\int Vs\,dt=Vo\right]$$

* علاقة o/p مع ال i/p هي Integration ← مقدار ال Amplification = $\frac{1}{RC}$

(إذا ما بدنا نكبر ← $RC=1$)

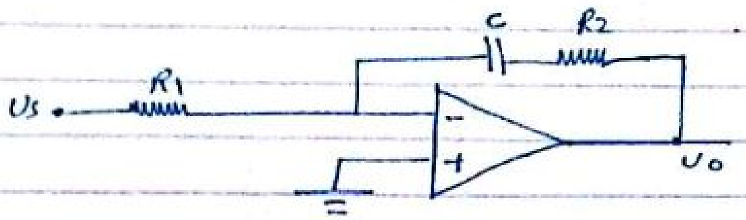
* Example : obtain the output Voltage for the following ckT :

①

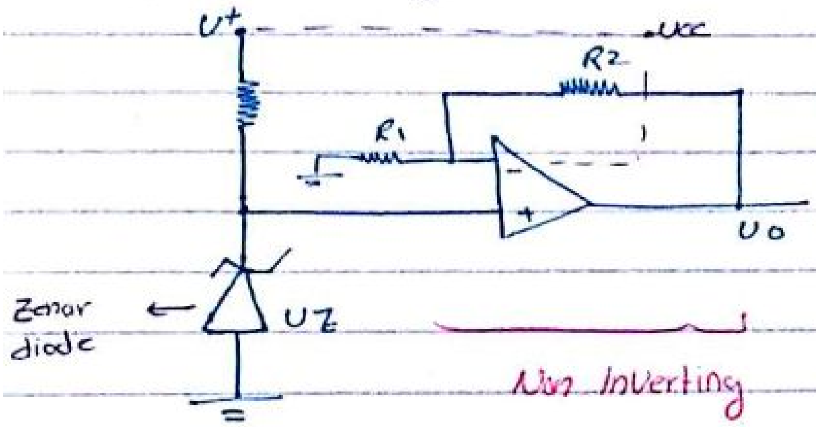


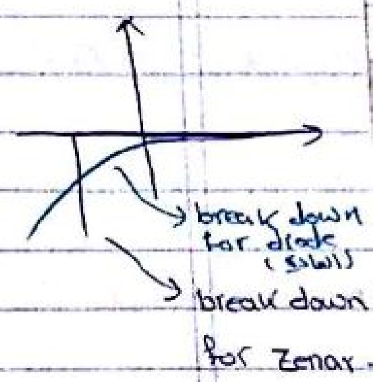
$V^+ - V^- = 0$

②



* Reference Voltage Source (P661)





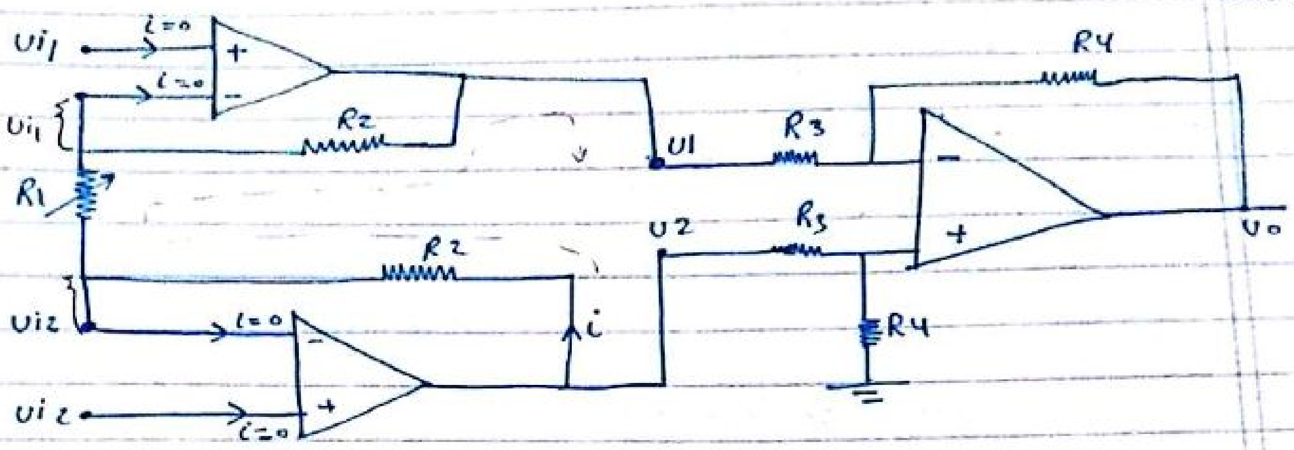
V^+ has to be greater than VZ.

* Assuming the Zenar Is In Breakdown:
عكس

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

* The Instrumentation Amplifier (P650)

فيها gain عالي وتلافي
تأثير ال noise



i/p (non Inverting) o/p (difference)

$$U_o = \frac{R_4}{R_3}(U_2 - U_1)$$

$$U_2 = R_2 i + R_1 i + R_2 i + V_1$$

$$U_2 - U_1 = (R_1 + 2R_2)\, i$$

$$i = \frac{U_{i2} - U_{i1}}{R_1}$$

$$\Rightarrow U_o = \frac{R_4}{R_3}\left(\frac{R_1 + 2R_2}{R_1}\right)(U_{i2} - U_{i1})$$

$$\Rightarrow U_o = \frac{R_4 (R_1 + 2R_2)(U_{i2} - U_{i1})}{R_3 R_1} \qquad / R_1$$

(=0)

$$\left[v_o = \frac{R_4}{R_3}\left(1+\frac{2R_2}{R_1}\right)(v_{i2} - v_{i1}) \right]$$

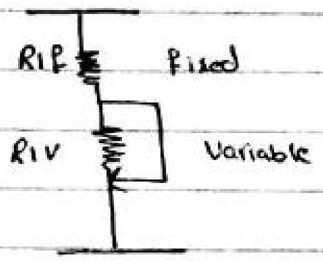
ثابت

بتتحكم في ال gain

* لو شلنا $\frac{R_4}{R_3}$ وضلينا نتحكم في ال gain من خلال $\frac{R_2}{R_1}$ ← بنثبت R_2 أو R_1 ونغير التاني ← الأحسن أثبت R_2 لأنه مستخدمة مرتين في الوصلة وصعب يكون التغيير متشابه على الشيئين لذلك أفضل نغير R_1 .

** Gain IS Varied by R_1.

$R_1 \Rightarrow$



بنفصلها إلى مقاومتين وحدة ثابتة ووحدة متغيرة.

23/8/2017

* Example: Design an IA (Instrumentation Amplifier) with gain Ranges from 12 to 810. use $\frac{R_4}{R_3} = 10$, $R_U = 50k\Omega$.

- Sol: $\frac{v_o}{v_2 - v_1} = \frac{R_4}{R_3}\left(1 + \frac{2R_2}{R_1}\right)$

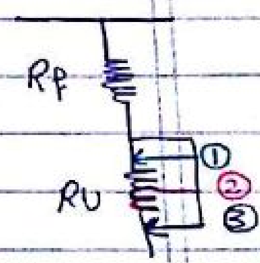
$$12 = 10\left(1 + \frac{2R_2}{R_f + R_U}\right) \quad \text{--- ①}$$

بنختار قيمة الأرقام بحيث المعادلة الأولى أقل من الثانية (الأرقام بشكل أكبر)

$$810 = 10\left(1 + \frac{2R_2}{\underbrace{R_f}}\right) \quad \text{--- ②}$$

أقل قيمة لـ R_1 هي R_f $(R_U = 0)$

$R_1 \rightarrow R_f + R_U$



$$12 = 10\left(1 + \frac{2R_2}{50 + R_f}\right)$$

مكان رأس السهم يدل على المقدار المأخوذ من RV مثلاً الحالة
① RV كاملة ② الجزء الرمزي
③ ولا جزء RU=0
(السهم بجعل Short ckT)

$\Rightarrow$ from ①:

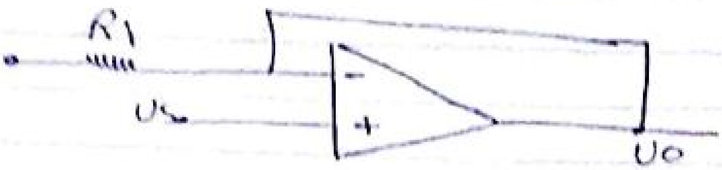
$$2 = \frac{20R_2}{R_f + 50} \Rightarrow R_f + 50 = 10R_2$$

$\Rightarrow$ from ②:

$$800 = \frac{20R_2}{R_f} \Rightarrow 400R_f = 10R_2$$

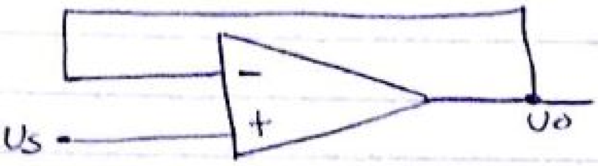
* Solution #2 :

$R_2 = 0\,\Omega$, $R_1 \neq 0\,\Omega$



* Solution #3 :

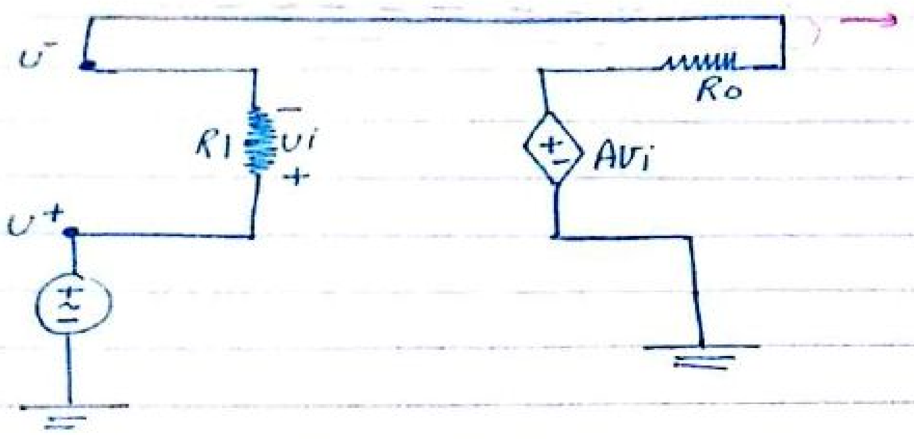
$R_2 = 0\,\Omega$, $R_1 = \infty\,\Omega$



⇓

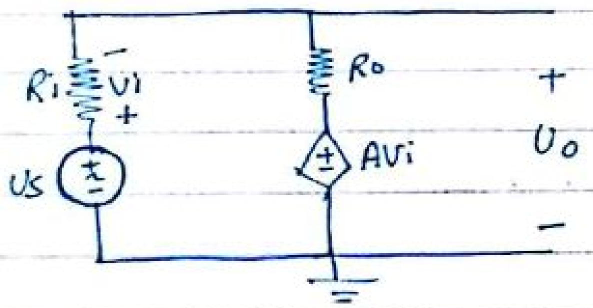
Although this simple ckt it has a voltage gain = 1, it has very high input resistance and very low output resistance, to prove this, consider th practical op_Amp model.

* practical op_ Amp :



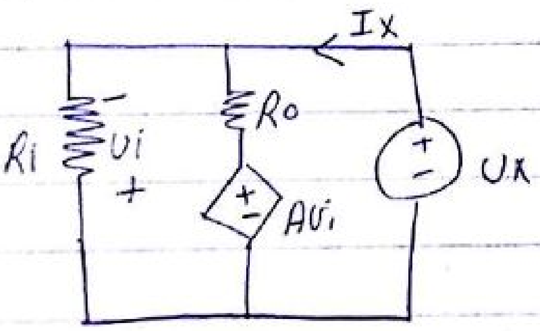
بدنت صار اكثر
output Res. = Ro

* Input R for op_ Amp = Ri



calculate the output Resistance :

(Kill Us and add UX)



$$R_o = \frac{U_X}{I_X} \quad , \quad \boxed{v_i = -U_X}$$

$$I_X = \frac{U_X - A v_i}{R_o} + \frac{-v_i}{R_i}$$

$$I_X = \left[\frac{1}{R_o} + \frac{A}{R_o} + \frac{1}{R_i} \right] U_X$$

$$\frac{1}{R_o} = \frac{I_x}{V_x} = \frac{1+A}{R_o} + \frac{1}{R_i}$$

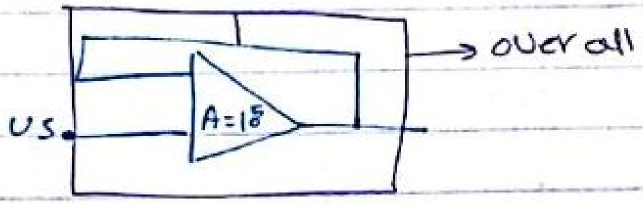
$\Longrightarrow$ $R_o = R_i \,//\, \frac{R_o}{1+A} \approx \frac{R_o}{1+A}$ Very extremly low

$\downarrow$

Suitable for a voltage buffer.

* overall gain of the ckt $= A = 1$ (العالم الواقعي)

* gain of op-Amp $= 10^5$.



* EX: Derive an expression for the Input Resistance of the ckt.

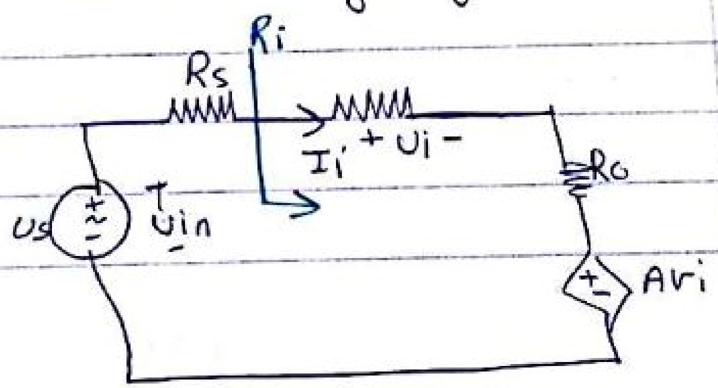
$\Longrightarrow$ Solution:

It should be extremly high.

(using this ckt):

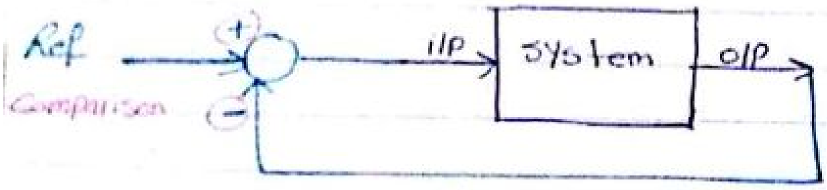
$$R_i = \frac{V_{in}}{I_i}$$

(7b)



* Ch 12 : Feedback Amplifier (P. 852)

⟹ a feedback system :



↓

This system has feedback.

* Ideal feedback Topologies (P. 863)

↓

Amplifier configurations

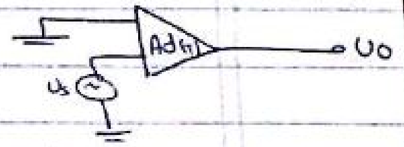
↓

4 configurations

(بناءً على ال i/p وال o/p ← voltage or current

for both) → Application حسب

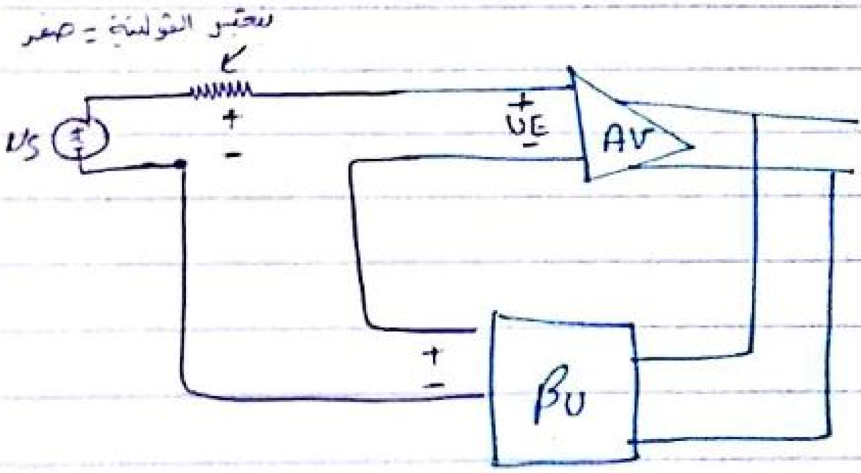
$Vo = Ad(Vs - 0)$



المشكلة أنه ال (Ad) gain

تتغير مع درجة الحرارة

* op-Amp → Voltage Amp



β: factor : constant

* $\boxed{VE = Vs - \beta Vo}$

الفولتيتين In parallel.

نسبة من الفولتية التي تتسلط ← β

الفولتية الطالعة فتي أرجعها نستخدل

نفاد ال i/p أو o/p .

* Shunt ≡ parallel

* Voltage in series in input but shunt in output.

* Curren " Parallel " " " Series " "
لأنه الأميتر بيتشبك ع التوالي .

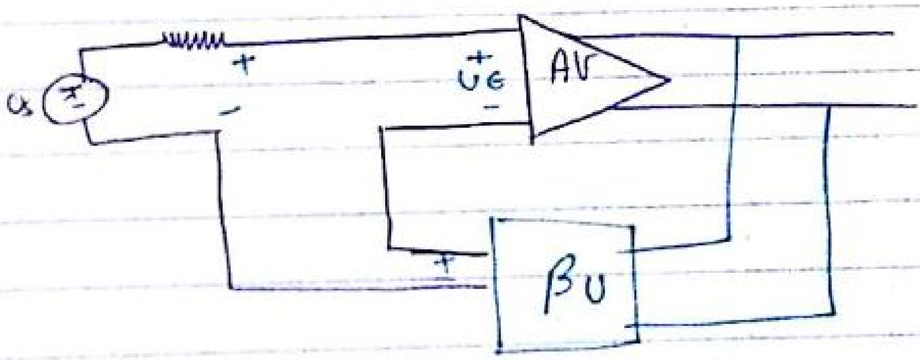
	i/p		o/p
①	Shunt	—	Shunt
②	Shunt	—	Series
③	Series	—	Series
④	Series	—	shunt

① Series — shunt

i/p — o/p

- comparison
- What is added in series ? ↓ Voltage

- measurments
- what is measured in shunt ? ↓ Voltage

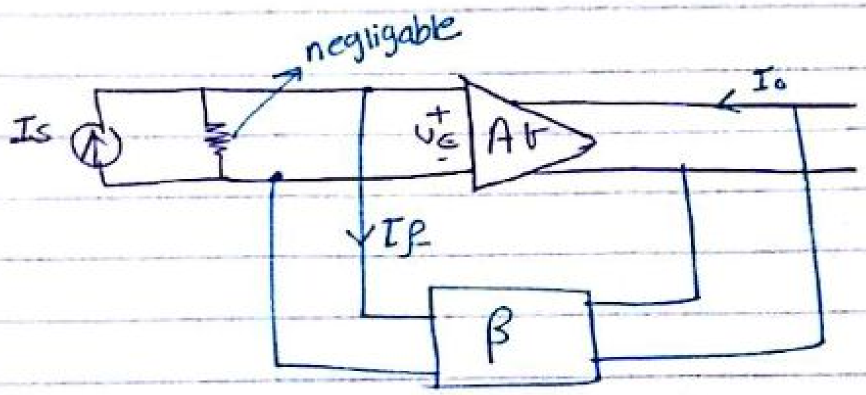


$v_\epsilon = v_s - \beta v_o$

(2) Shunt — Series

i/p — o/p

- Comparasion — measurments
- current — current



$I_\epsilon = I_s - I_f$

(schematic – electronic Diagram)

* EX : Draw the shunt – shunt & series – series Amplifier configurations ?

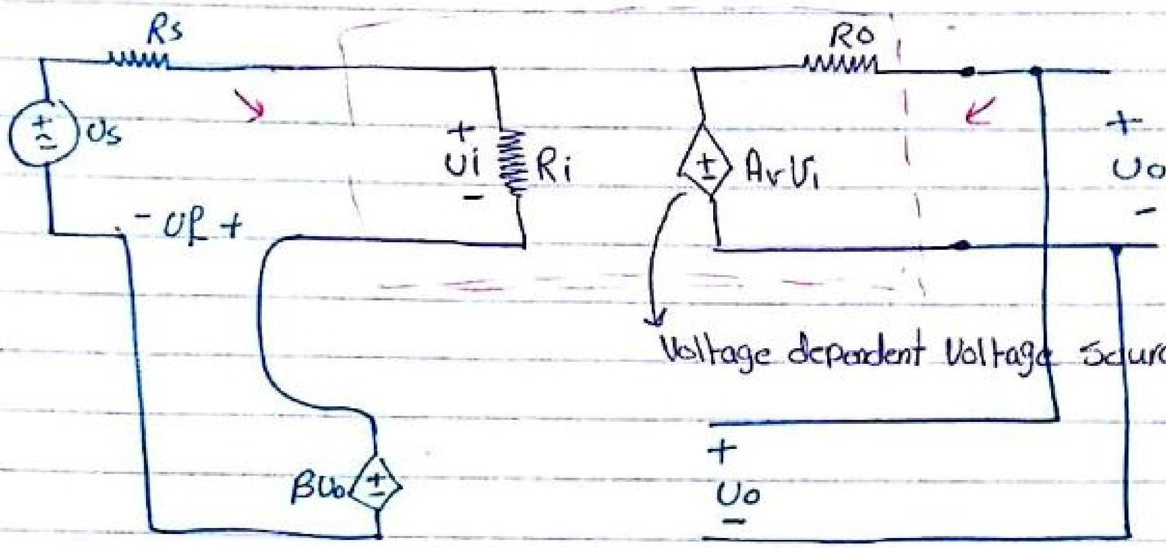
(see book p. 863).

* Series _ shunt Amplifier.

↳ i.e the output Voltage is Adjusted (controlled) by the reference Voltage.

لسختار configuration مناسبا

open loop Amplifier (without feedback)



(Assume No loading effect نستعمل الا)

→ Assuming U_{Rs} is negligable:

$$U_s = U_i + U_f$$

$$U_i = U_s - U_f$$

$$U_f = \beta U_o = \beta A V_i$$

$$\rightarrow V_i = U_s - A\beta V_i$$

$$V_i = \frac{1}{1 + A\beta} U_s$$

(80)

$$v_o = A v_i = \frac{A}{1+A\beta} v_s$$

$$\left[\frac{v_o}{v_s} = A_v = \frac{A}{1+A\beta} < A \right]$$ Voltage gain (close loop)

$\Rightarrow$ open loop gain $= A$.

الفائدة هي ال Stability

- suppose A varies but $A\beta \gg 1$

$$\left[A_{vf} = \frac{1}{\beta} \right]$$

$\beta \rightarrow$ design parameter

So, if $\beta = 0.01 \rightarrow A_{vf} = 100 \rightarrow$ stable (constant, not varying)

→ Input Resistance:

$$R_{if} = \frac{V_{if}}{I_\epsilon} = \frac{R_i I_\epsilon + \beta V_o}{I_\epsilon}$$

$$= \frac{R_i I_\epsilon + \beta A_V R_i I_\epsilon}{I_\epsilon}$$

$$= (1 + A\beta) R_i$$

⟹ $R_{input} = R_i$ → In open loop

. Close loop أقل من ال

* The feedback output Resistor.

→ Assuming 0 Voltage drop on R_s.

$$V_o = V_x$$

$$I_x = \frac{V_x - A V_\epsilon}{R_o}$$

$$V_\epsilon + V_f = 0$$

$$V_\epsilon = -V_f$$

$$V_\epsilon = -V_f$$
$$= -\beta V_o$$
$$= -\beta V_x$$

$$I_x = \frac{V_x + A\beta V_x}{R_o} = \frac{(1+A\beta)}{R_o} V_x$$

$$R_{of} = \frac{V_x}{I_x} = \left(\frac{R_o}{1+A\beta}\right) \longrightarrow$$ output Resistance in close loop.

أي

* output Resistance in open loop $= R_o$

* i.e the output Resistance with feedback have been reduce.

* shunt – shunt.

$\downarrow R_i , R_o$

*أي شي Parallel بقل

و series بزيد.

* Series – series

$\uparrow R_i , R_o$

→ current gain → see book → use RL or short CKT.

* EX: Verify A_{vf}, A_{if} & R_{if}, R_{of} for the Remaining Three Amplifiers configurations:

1. Shunt - Shunt
2. Series - Series
3. Shunt - Series

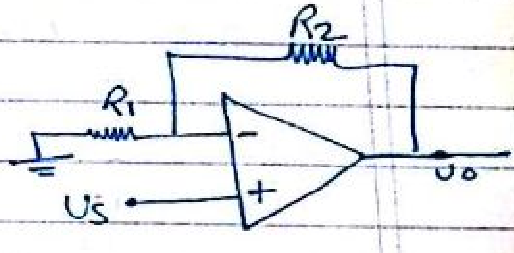
$$\Rightarrow R_f + 50 = 400\,R_f \quad \Rightarrow R_f = \frac{50}{399}\,k\Omega \approx 125\,\Omega$$

$$R_2 = \frac{R_f + 50}{10}\,k\Omega = \frac{50.125}{10}\,k\Omega = 5.0125\,k\Omega = 5012\,\Omega$$

* مهم في ال op-Amp الرسمات و الحسابات.

* Example : A Return to Non-Inverting Amplifier, using :

$$\frac{V_o}{V_s} = 1 + \frac{R_2}{R_1} = \frac{R_1 + R_2}{R_1}$$



$\Rightarrow$ choose R_1 & R_2 to get $\frac{V_o}{V_s} = 1$?

Solution #1 :

$$R_2 \neq 0\,\Omega \,,\; R_1 = \infty\,\Omega$$