Amplifires

NoteBook

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By: Ahmad Fatafta

POWER UNIT
ELECTRICAL ENGINEERING

#Ch.6

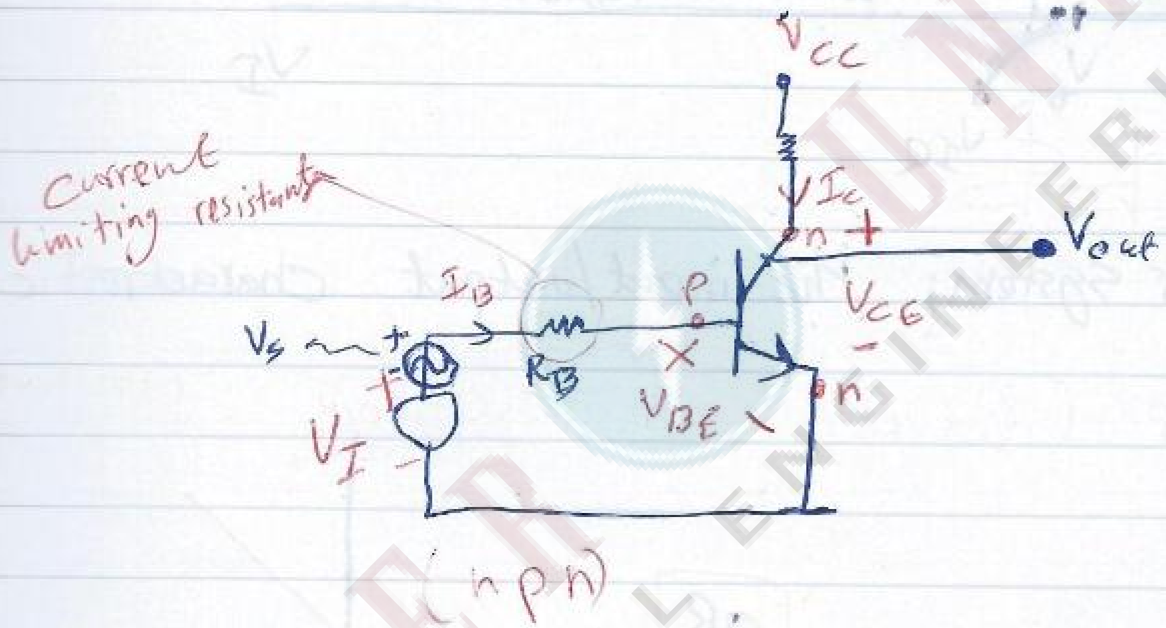
p. 371

24/6

⟹ BJT Amplifiers:

* The use of the BJT as a linear device.

→ Consider the following cct.



* if $V_I < V_\gamma \Rightarrow I_B = 0 \Rightarrow I_C = 0 \Rightarrow V_{out} = V_{CE} = V_{CC}$

* if $V_I \geq V_\gamma \Rightarrow \boxed{I_B = \frac{V_I - V_\gamma}{R_B}}$

$\Rightarrow \boxed{I_C = \beta I_B}$

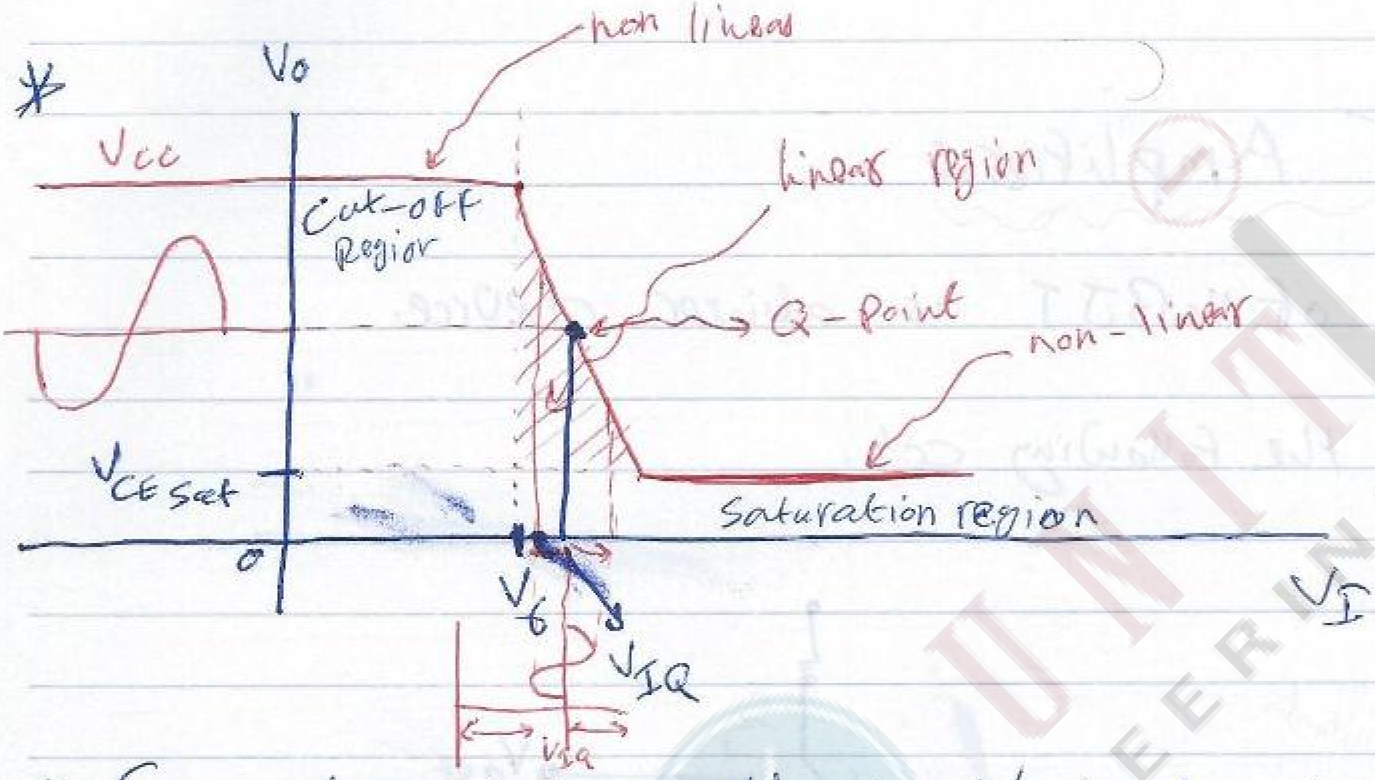
$\Rightarrow \boxed{V_0 = V_{CE} = V_{CC} - R_C \cdot \beta \frac{(V_I - V_\gamma)}{R_B}}$

Valid as long as $V_{CE} > V_{CE\,sat} \approx 0.2 \to 0.3$

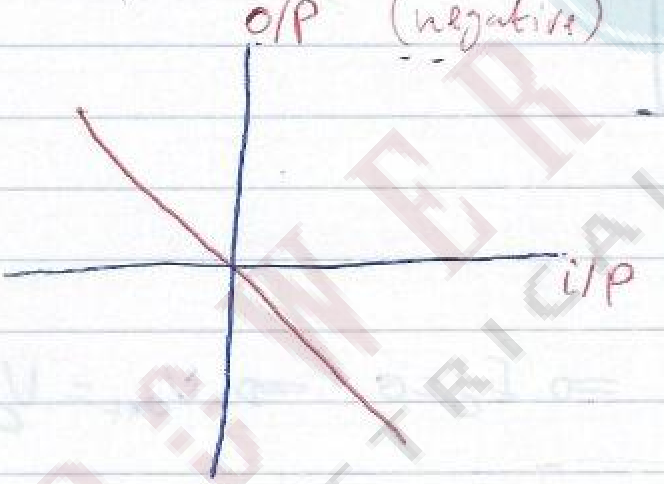
* in all transistor cct, we can't obtain any voltages larger than V_{CC}.

* Consider $\boxed{V_{CE_{sat}} = 0.2}$ in calculations.

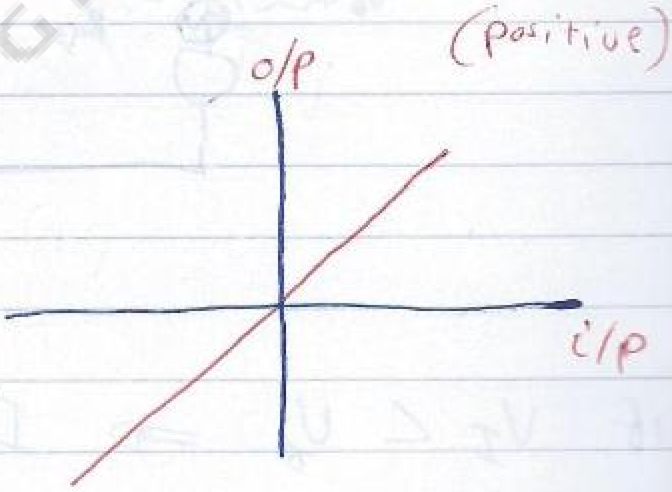
*



* For a linear system; the input/output charactrestics



OR



*

Subject lec # 2 Date 24/6/2014 No.

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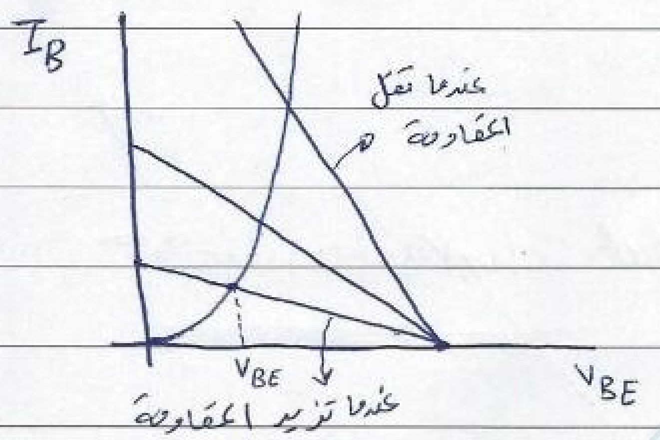
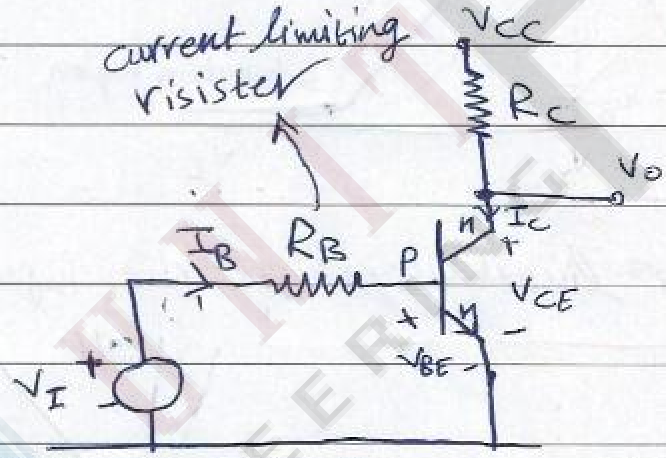
* BJT Amplifier :-

The use of BJT as ~~following~~ a linear Device

consider the following CKT.





*if $V_I < V_\gamma \rightarrow$ تيار الديود صفر

$I_B = 0 \Rightarrow I_C = 0 \Rightarrow V_o = V_{CE} = V_{CC}$

Idealization

* إذا وضعنا DC source بدون مقاومة R_B يجب أن تكون قيمتة قريبة من 0.7 V وإذا كانت كبيرة سوف يمر تيار كبير يؤدي إلى تلف الترانزستور.

*if $V_I \geq V_\gamma \Rightarrow I_B = \frac{V_I - V_\gamma}{R_B}$

$$I_C = \beta \frac{(V_I - V_\gamma)}{R_B} \Rightarrow \boxed{V_o = V_{CE} = V_{CC} - R_C \cdot \beta \frac{(V_I - V_\gamma)}{R_B}}$$

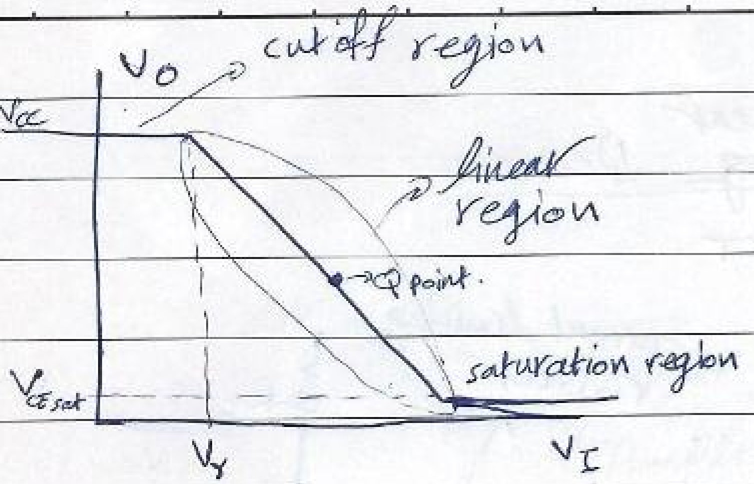
valid as long as

$V_{CE} > V_{CE sat} \approx 0.2$

* يبقى I_B يزداد ويؤدي إلى ازدياد V_{CE} إلى أن نصل إلى قيمة لـ V_{CE} ثابتة مع بقاء تغير I_B وتسمى هذه النقطة

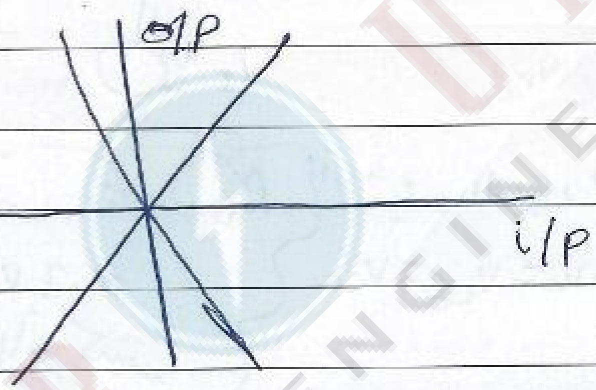
$V_{CE \, saturation} \approx 0.2V$

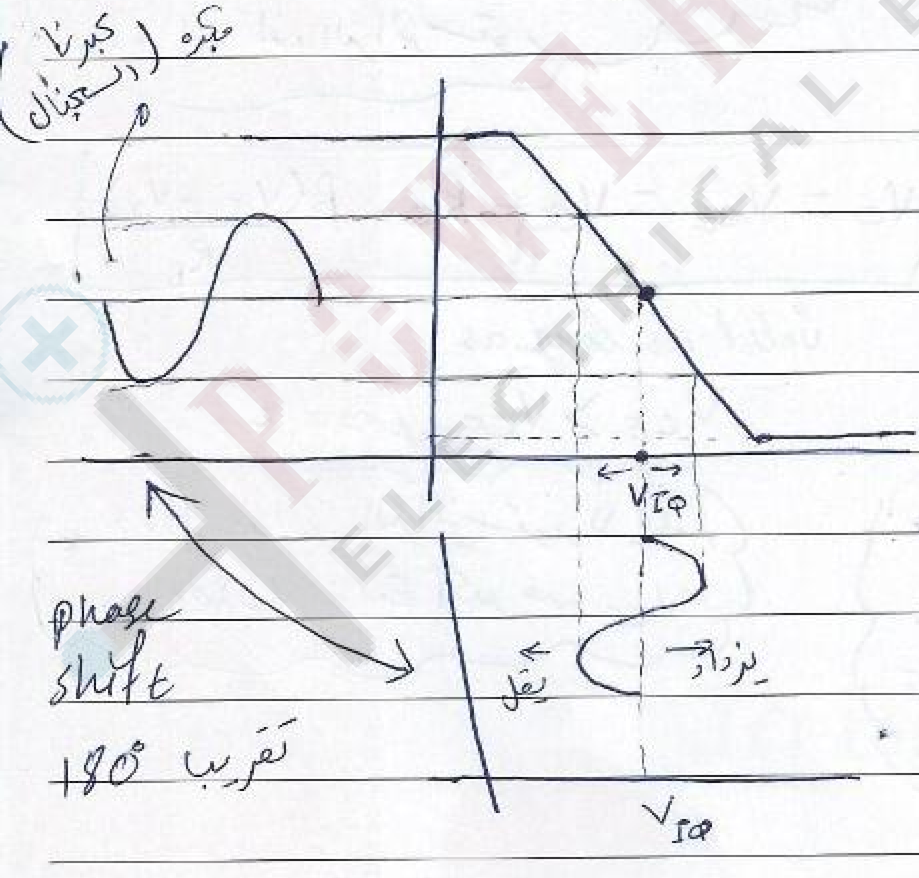
* في كل دوائر الترانزستور لا يمكن أن نحصل على فولتية أكبر من V_{CC}

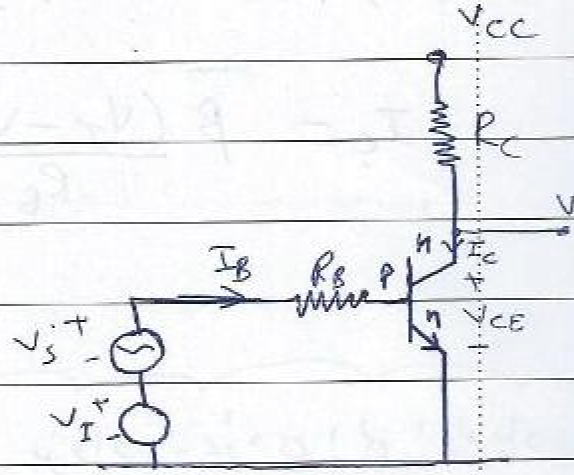


* لا يمكن ان نقول عنه linear لانه
لا يتغير ال output مع تغير ال input
في كل الحالات

* For linear system the input-output characteristic :-







Subject lec#3 Date 25/6/2014 No.

* A matter of Notation :-

Convenient naming of variables together subscripts helps in understanding and easy following of writing.

V_{DD} , I_D ; refer to dc quantities.

v_d , i_d , v_{gs} ; refer to ac quantities (time varying)

v_{CE} , v_{GS} , v_{BE} , i_B ; refer to dc and ac (mixture of quantities)

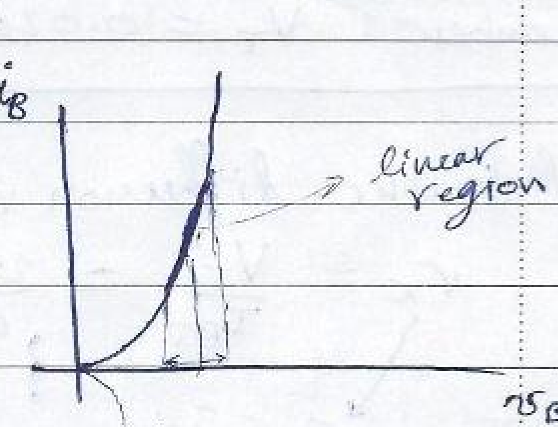
so $i_B = \underset{\substack{\text{due to}\\ V_I}}{I_B} + \underset{\substack{\text{due to}\\ v_s}}{i_b}$ $\qquad$ $v_{CE} = \underset{\substack{\text{due to}\\ V_I \,\&\, V_{CC}}}{V_{CE}} + \underset{\substack{\text{due to}\\ v_s}}{v_{ce}}$

بالإضافة إلى بقية المقاومات $\qquad$ بالإضافة إلى بقية المقاومات

* Linearization of the BJT :-

Consider

$$i_B = \frac{I_s}{\beta} e^{\frac{v_{BE}}{V_T}}$$



بدأ من الصفر بقيمة $\frac{I_s}{\beta}$ قليلة جداً

$$I_{BQ} + i_b = \frac{I_s}{\beta} e^{\frac{V_{BE} + v_{be}}{V_T}}$$

$$= \frac{I_s}{\beta} e^{\frac{V_{BE}}{V_T}} \cdot e^{\frac{v_{be}}{V_T}}$$

$$= I_{BQ} \, e^{\frac{v_{be}}{V_T}}$$

$$= I_{BQ} \left(1 + \frac{v_{be}}{V_T} + \underbrace{\frac{1}{2!}\left(\frac{v_{be}}{V_T}\right)^2 + \cdots}\right)$$

عن طريق أن $V_T \gg v_{be}$ وبالتالي سوف يكون الإهمال لهم وذلك عن طريق تقليل v_{be} ⟸ neglected to get a linear model

$$e^x = 1 + x + \frac{x^2}{2!} + \frac{x^3}{3!} + \cdots$$

$$e^{jx} = 1 + jx + \frac{(jx)^2}{2!} + \cdots$$

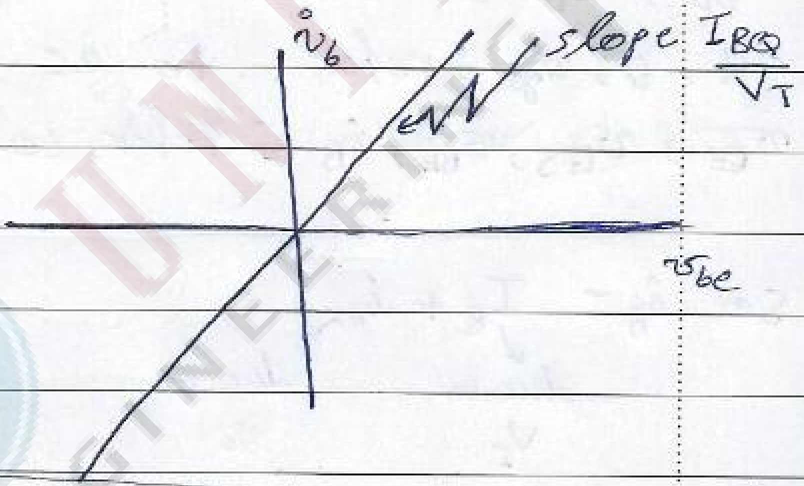
Subject Date No.

$$\boxed{\cos x + j\sin x = \left(1 - \frac{x^2}{2!} + \frac{x^4}{4!} + \cdots\right) + j\left(x - \frac{x^3}{3!} + \cdots\right)}$$

* so if $v_{be} \ll V_T$ then

$$\cancel{I_{BQ}} + i_b = \cancel{I_{BQ}}\left(1 + \frac{v_{be}}{V_T}\right)$$

$$\boxed{i_b = \frac{I_{BQ}}{V_T} v_{be}}$$

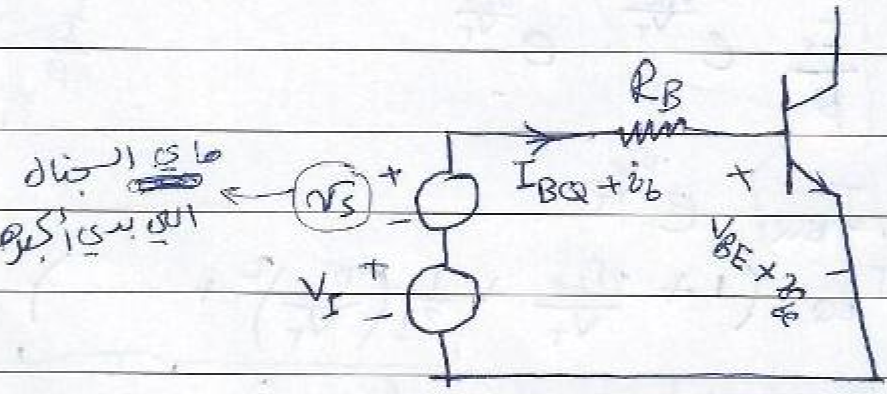


* if $v_{be} = 10\,mV$
then, the truncated exponential is 90% of the exact exponential

* Remember: $V_T = 0.026$

* define the diffusion resistance as r_π (base-emitter resistance)
as $r_\pi = \frac{V_T}{I_{BQ}} = \frac{v_{be}}{i_b}$

نسبة تغير v_{be} ع i_b



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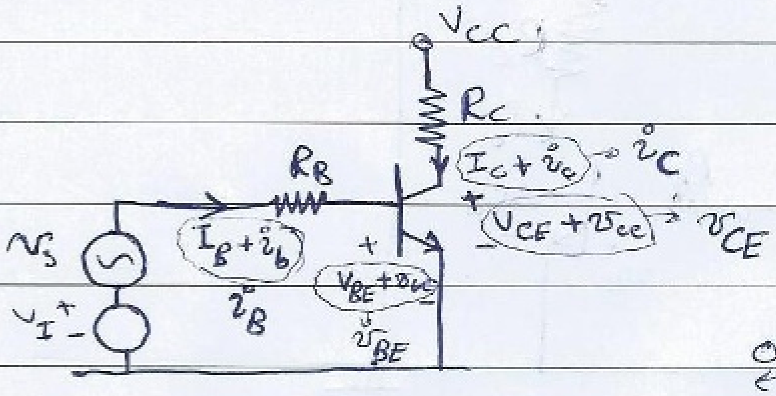
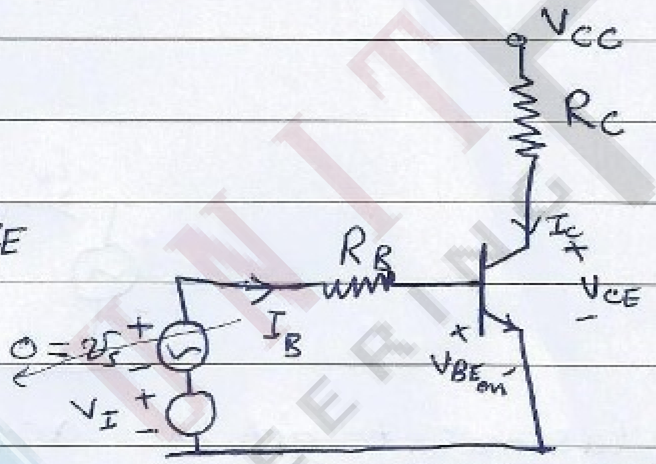
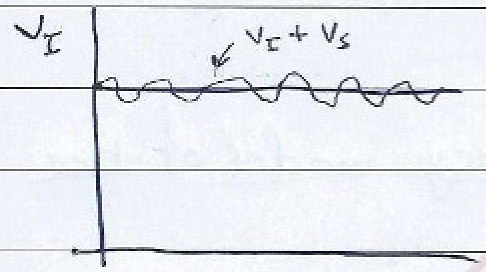
* connections of source and resistors :-

small signal Equivalent circuit

with reference to the following circuit







* إذا بدنا إياه يعمل في منطقة linear - يجب أن تكون قيمة الـ v_s قليلة

* إذا كانت كبيرة إما بتشغل في cutoff region أو في منطقة saturation region

$$V_I + v_s = R_B i_B + v_{BE}$$

$$= R_B I_B + R_B i_b + V_{BEon} + v_{be}$$

$$\underbrace{V_I} + v_s = \underbrace{R_B I_B + V_{BEon}} + R_B i_b + v_{be}$$

$$\Rightarrow v_s = R_B i_b + v_{be}$$

consider the out-put circuit

$$V_{CC} = R_C i_C + v_{CE}$$

$$V_{CC} = R_C I_C + R_C i_c + V_{CE} + v_{ce}$$

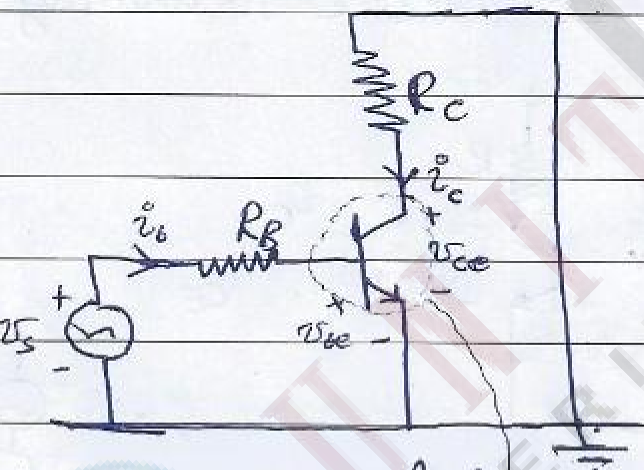
$$\underline{V_{CC}} + 0 = \underline{R_C I_C + V_{CE}} + R_C i_c + v_{ce}$$

$$\Rightarrow R_c i_c + v_{ce} = 0$$

$\Rightarrow v_s = R_B i_b + v_{be}$

$R_C i_c + v_{ce} = 0$

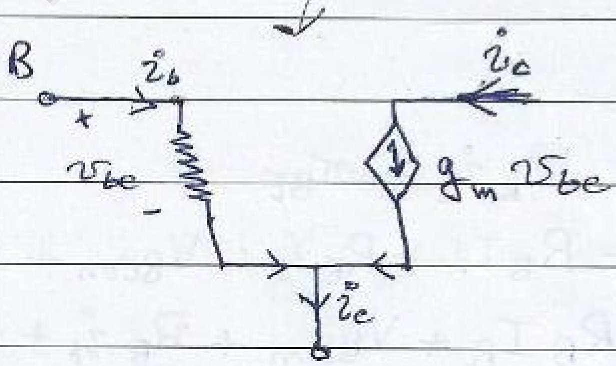
* أوجد دائرة تمثل المعادلتين وذلك عن طريق
جعل الـ DC sources → short circuit → في حالة V
→ open circuit → في حالة I



conclusion: to get the ac equivalent circuit kill the independent sources.

* To get the small signal low frequency model of the npn BJT :-

$v_{be} = r_\pi i_b$



Using

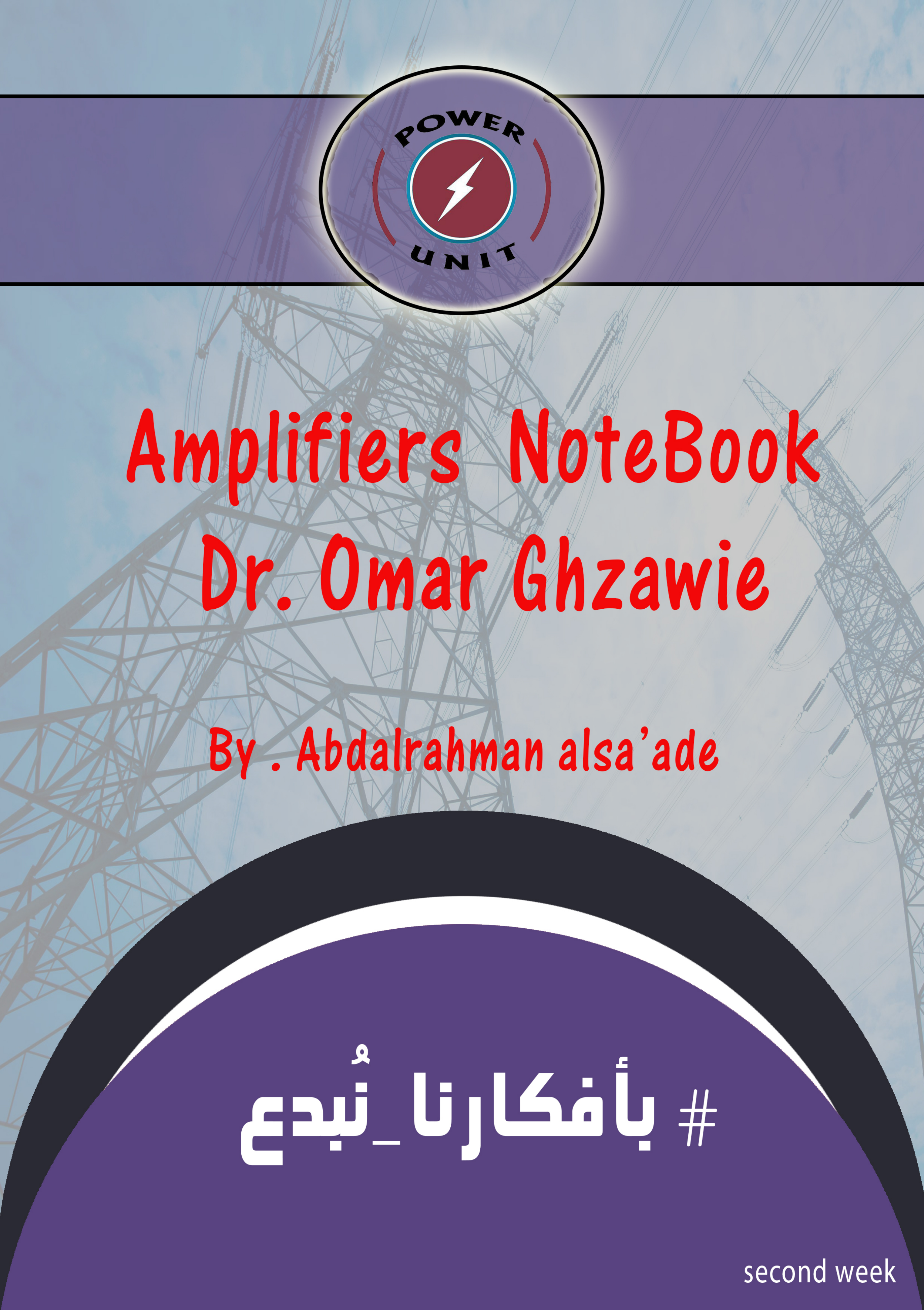
$$\Delta i_c = \left.\frac{\partial i_c}{\partial v_{BE}}\right|_{Q\text{-point}} \Delta v_{BE}$$

$$i_c = \left.\frac{\partial i_c}{\partial v_{BE}}\right|_{Q\text{-point}} v_{be}$$

$$\frac{\partial}{\partial v_{BE}}\left(I_s e^{\frac{v_{BE}}{V_T}}\right) = \frac{1}{V_T} I_{CQ}$$

$$i_c = \frac{I_{CQ}}{V_T} v_{be}$$

$$i_c = \boxed{g_m} v_{be} \longrightarrow \text{transconductance.}$$



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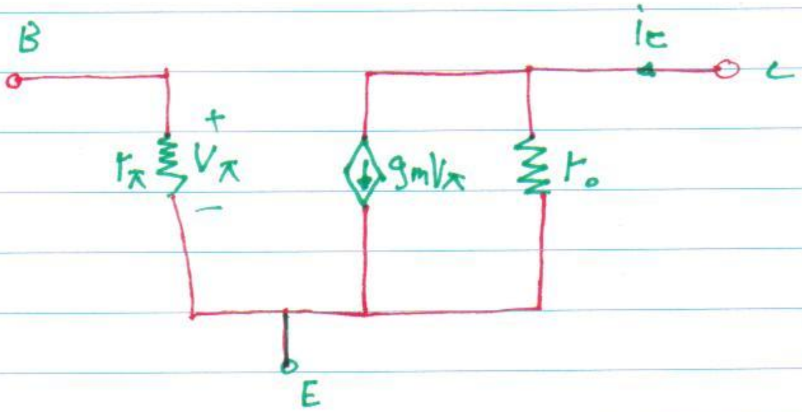
By . Abdalrahman alsa'ade

بأفكارنا_نُبدع

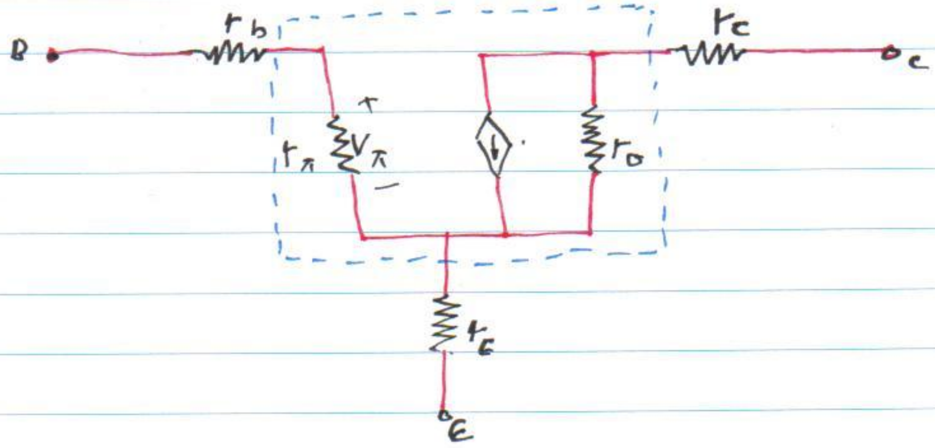
second week

29-6-2014
Sunday

V_o is Known as the output resistance of the transistor this reflected on the model as shown:



* An Extand BJT model :



Let : $r_o = \infty$

$r_c = r_b = r_c = 0$

30-06-2014
monday

* For a particular transistor ckt:

given: $i_B = \underbrace{20*10^{-6}}_{DC} + \underbrace{0.0008\sin\omega t}_{AC}$ A

$\beta DC = 100$

Find ① I_{BQ}
② r_π
③ g_m
④ β_{ac}
⑤ i_b
⑥ I_{CQ}
⑦ i_c

Sol...

1) $I_{BQ} = 20*10^{-6} = \boxed{20\mu A}$

2) $r_\pi = \frac{V_T}{I_{BQ}} = \frac{V_T}{I_{CQ}/\beta_{DC}}$

$= \frac{25\,mV}{20\mu A} = \frac{0.025}{20\,\mu A}$

$= \boxed{1.25\,k\Omega}$

③ $I_{CQ} = \beta_{DC} * I_{BQ}$

$= 100 * 20\,\mu A$

$= 2000\,\mu A$

$= \boxed{2\,mA}$

④ $g_m = \dfrac{I_{CQ}}{V_T}$

$= \dfrac{2\,mA}{25\,mV} = \dfrac{1}{12.5}$

$= 0.08\ A/V$

$= \boxed{80\ mA/V}$

⑤ $\beta_{AC} = g_m * r_\pi$

$= 80 * 1.25$

$= \boxed{100}$

⑥. $i_b = 0.0008 \sin \omega t$ A

$= 0.8 \sin \omega t$ mA

⑦

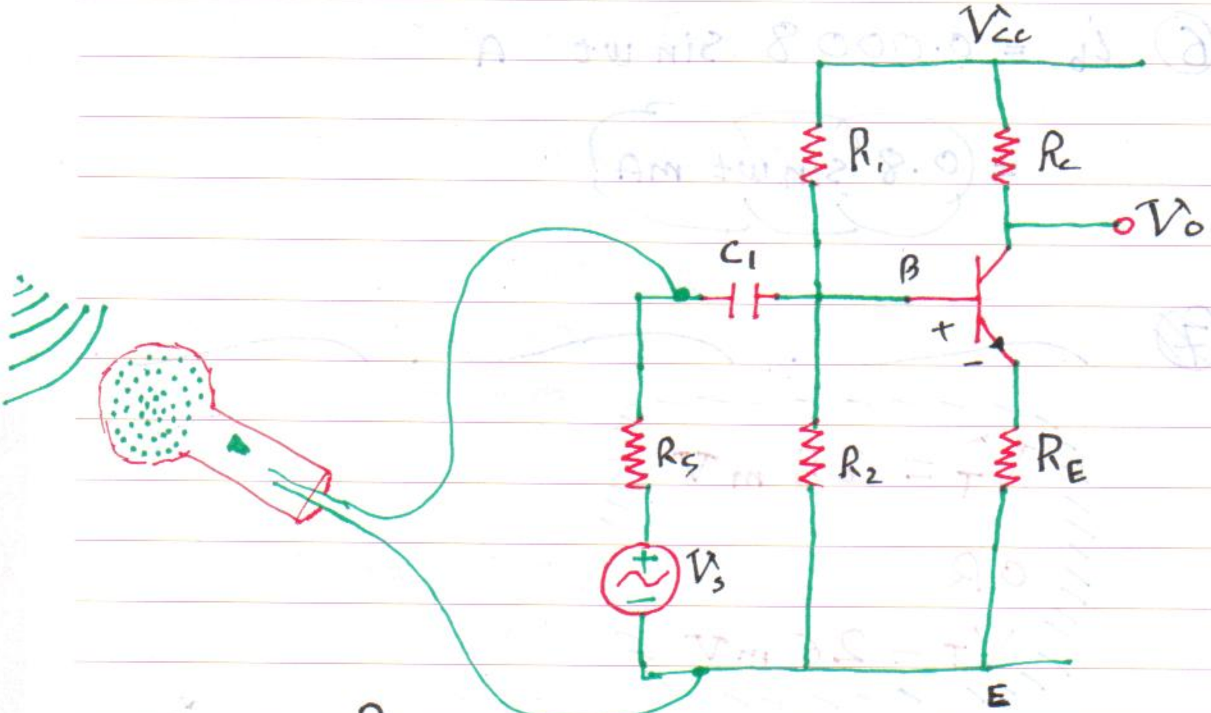
$V_T = 25$ mV

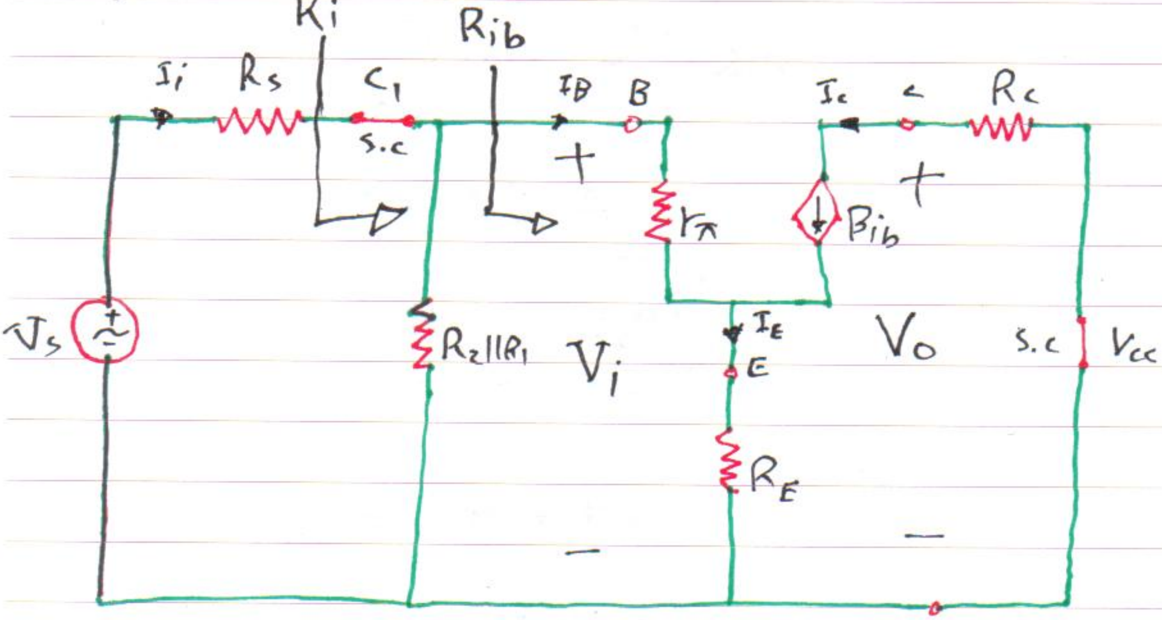
OR

$V_T = 26$ mV

1-07-2014

* Common Emetter *





*R_i: input (R) seen by (R_s).

*R_{ib}: (R) input base

* the input resestance Looking into the base (R_{ib}) is:

$$R_{ib} = \frac{V_i}{i_b} = \frac{r_\pi * \cancel{i_b} + R_E(1+\beta)\cancel{i_b}}{\cancel{i_b}}$$

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

* the input resestance seen by (R_s) is (R_i):

$$R_i = \frac{V_i}{I_i} = \frac{R_{ib} * \cancel{i_b}}{\cancel{i_b} + \frac{R_{ib} * \cancel{i_b}}{R_1 \parallel R_2}}$$

$$= \frac{R_{ib}}{1 + \frac{R_{ib}}{R_1 \parallel R_2}}$$

$$\boxed{= R_1 \parallel R_2 \parallel R_{ib}}$$

2-07-2014

$$* \; V_o = -R_c * i_c = -R_c * \beta * i_b$$

$$= -\beta * R_c * \frac{V_i}{R_{ib}}$$

$$\boxed{= \frac{-\beta * R_c}{R_{ib}} * \frac{R_i}{R_i + R_s} * V_s}$$

$$A_V = \frac{V_o}{V_s} = \frac{-\beta * R_c}{r_\pi + (1+\beta)R_E} * \frac{R_1 \| R_2 \| (r_\pi + (1+\beta)R_E)}{R_1 \| R_2 \| (r_\pi + (1+\beta)R_E)} \frac{\cancel{V_s}}{\cancel{V_s}}$$

$* \text{ if } R_i >> R_s :$

$$A_V = \frac{-\beta \; R_c}{R_{ib}} = \frac{-\beta \; R_c}{r_\pi + (1+\beta)R_E}$$

$* \text{ if } (1+\beta)R_E >> r_\pi :$

$$A_V = \frac{-\beta \; R_c}{(1+\beta)R_E}$$

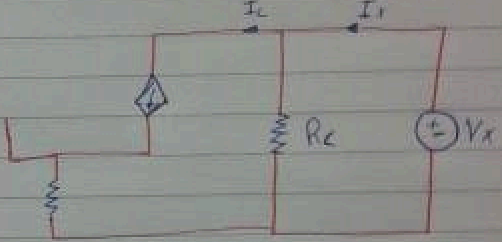
Since $\beta >> 1 : \beta \cong \beta + 1$

$$\boxed{A_V = \frac{-R_c}{R_E}} \qquad \boxed{|A_V| < 20}$$

3-7-2014

* for (common-emmitter); there are:

1- current gain
2- voltage gain



$$R_o = \frac{V_x}{I_x} = \frac{V_x}{\frac{V_x}{R_c} + \beta I_b} \quad \text{---} ①$$

if $\boxed{I_b = \text{zero}}$

$$R_o = \frac{V_x}{\frac{V_x}{R_c}} = \boxed{R_c}$$

$$A_V = -\frac{R_c}{r_\pi + (1+\beta)R_E} = \boxed{\frac{R_c}{R_c + R_s}}$$

[illegible]

* For Voltage Amplifier (i/p, o/p):

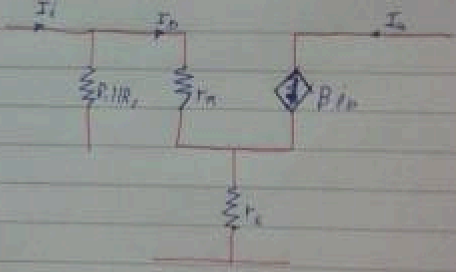
"R_i" is ideally ($\infty\,\Omega$)

Practecally its $R_i \gg R_s$

*"i_i" depends on "V_{cc}" and "i_i"

*** Current gain ***

$$A_i = \frac{I_o}{I_i}$$



$$= \frac{\beta i_b}{\frac{V_i}{R_1 \| R_2} + i_b}$$

$$= \frac{\beta I_B'}{\frac{(r_\pi + (1+\beta)R_E) I_b}{R_1 \| R_2} + I_b}$$

$$= \frac{\beta}{1 + \frac{r_\pi + (1+\beta)R_E}{R_1 \| R_2}}$$

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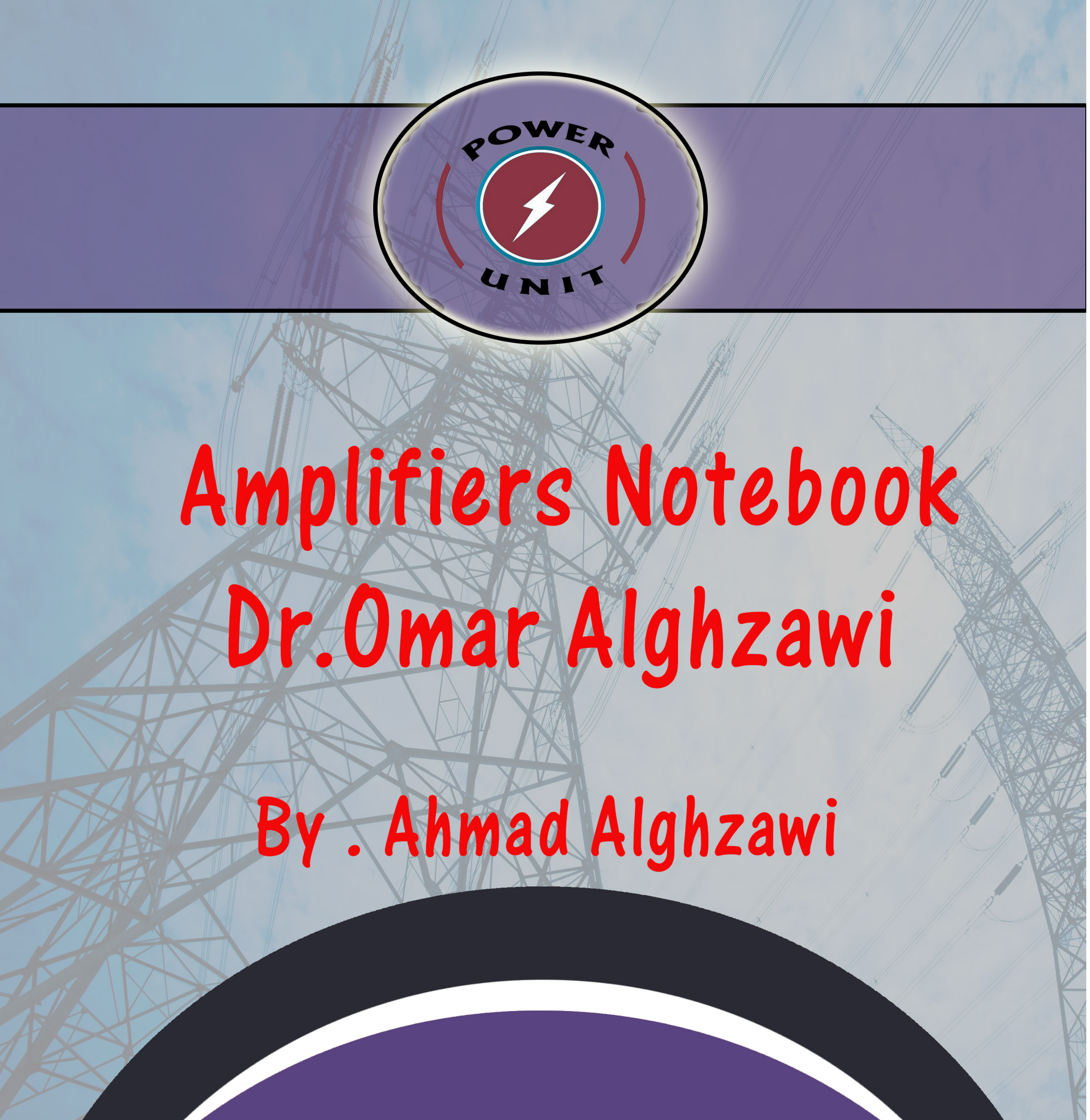

Amplifiers Notebook
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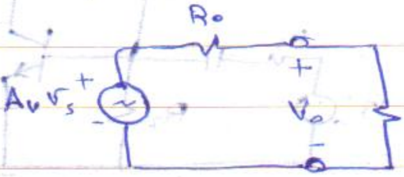
By . Ahmad Alghzawi

بأفكارنا_نُبدع

third week

amplifiers   د/ محمد عبد الغفار [illegible]   6/7/14 mon.

* so from the load point of view, it experiences the following cct.



$$V_o = \frac{R_L}{R_o + R_L}(A_v v_s)$$

* to get maximum output, ~~R~~ R_o should be $<< R_L$. ideally we require $R_o = 0\,\Omega$.

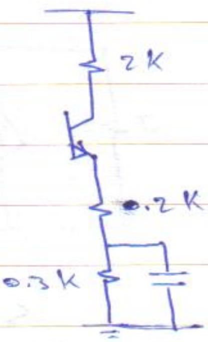
---

ex: consider the CE amplifier, based on $A_v = \frac{-R_c}{R_E}$ ~~Design where R_E =~~ where $R_E = 500\,\Omega$ (for dc analysis)

choose R_c ~~[illegible]~~ such that $A_v = -10$
$R_o = 2K\Omega$

$R_o = R_c = 2K\Omega$

so $A_v = \frac{-R_c}{R_E} = -4$



for ac analysis

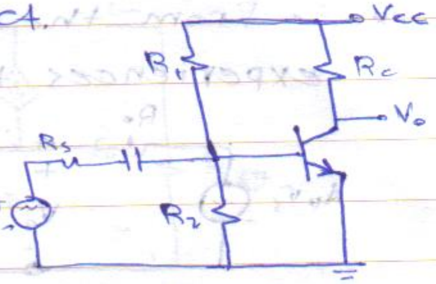
* trick

subdivide R_E into $200\,\Omega$ & $300\,\Omega$ (bypassed by a large capacitance) 10's of μF

amplifiers

7/7/14 mon

ex: consider the following cct.



* no need to calculate from scratch

it is a special case of the CE configuration i.e $R_E = 0$

$$R_{ib} = r_\pi + (1+\beta)R_E \Big|_{R_E=0} = r_\pi$$

$$R_i \cong R_1 // R_2 // r_\pi \approx r_\pi \text{ generally}$$

* i.e R_i is reduced considerably (considered a disadvantage).

$$A_v = \frac{-\beta R_c}{r_\pi + (1+\beta)R_E} \frac{R_i}{R_i + R_s}\Big|_{R_E=0}$$

$$\approx \frac{-\beta R_c}{r_\pi} \frac{r_\pi}{r_\pi + R_s} = \frac{-g_m r_\pi R_c}{r_\pi + R_s}$$

$$\doteq -g_m R_c \text{ provided } R_s \ll r_\pi$$

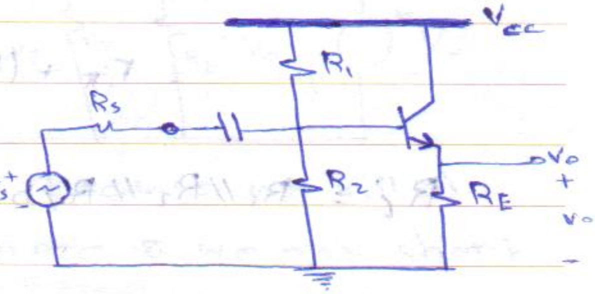
$$\text{so } g_m R_c > \frac{R_c}{R_E}$$

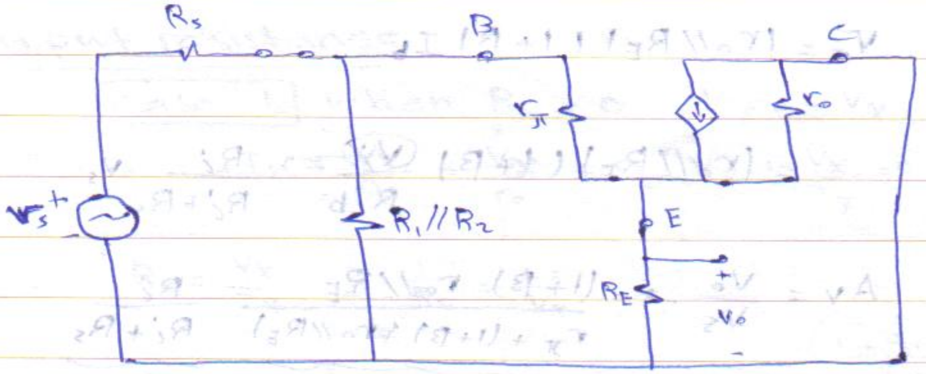
$$R_o = R_c\Big|_{R_E=0} = R_c$$

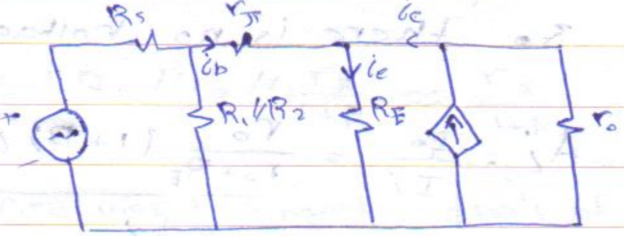
$A_i =$

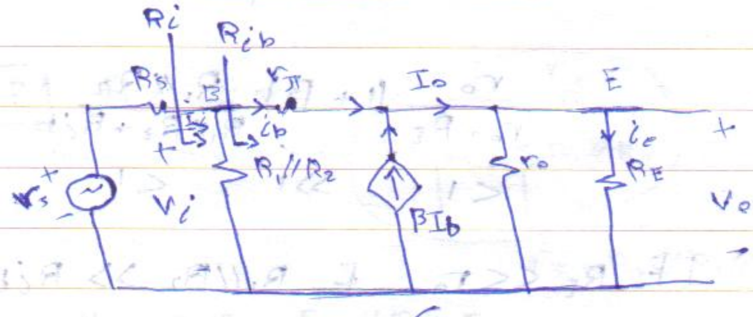
8/7/14 tues

* the common collector (Emitter Follower) Amp.









$A_v < 1$

take the outer loop, there is voltage drop on R_s & r_π so $V_o < V_s$

$$-V_s + IR_s + I_b r_\pi + V_o = 0$$

أحمد عمر محمد الغزاوي

$$R_{ib} = \frac{V_i}{I_b} = \frac{r_\pi I_b + (1+\beta) I_b (r_o // R_E)}{I_b}$$

$$= r_\pi + (1+\beta)(r_o // R_E)$$

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

$$V_o = (r_o // R_E)(1+\beta) I_b$$

$$= (r_o // R_E)(1+\beta) \frac{\boxed{V_i}}{R_{ib}} \rightarrow \frac{R_i}{R_i + R_s} V_s$$

$$A_v = \frac{V_o}{V_s} = \underbrace{\frac{(1+\beta)\ r_o // R_E}{r_\pi + (1+\beta)(r_o // R_E)}}_{<1} \underbrace{\frac{R_i}{R_i + R_s}}_{<1} \quad < 1$$

So there is no voltage gain.

$$A_i = \frac{I_o}{I_i} = \frac{\frac{r_o}{r_o + R_E}(1+\beta) i_b}{I_i} = \frac{\frac{r_o}{r_o + R_E}(1+\beta) \frac{R_1 // R_2}{R_1 // R_2 + R_{ib}} \cancel{I_i}}{\cancel{I_i}}$$

$$= \underbrace{\frac{r_o}{r_o + R_E}}_{<1} \underbrace{(1+\beta)}_{\gg 1} \underbrace{\frac{R_1 // R_2}{R_1 // R_2 + R_{ib}}}_{<1} \quad \underline{\underline{> 1}}$$

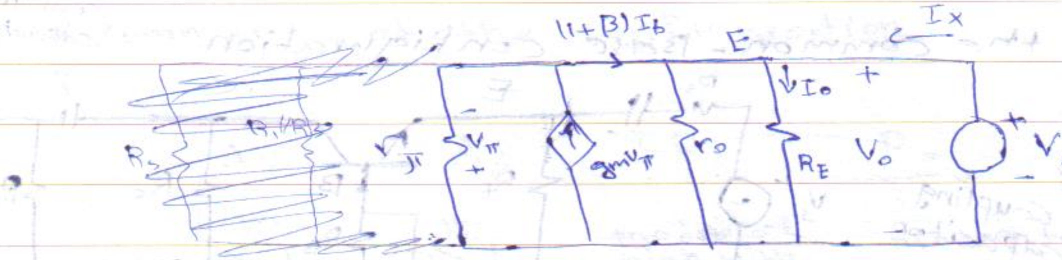
if $R_E \ll r_o$ & $R_1 // R_2 \gg R_{ib}$ then

$$A_i = 1 + \beta$$

amplifiers

13

9/7/14 wed



* we took out $R_1 // R_2$ because we killed the indep. voltage source & we got short cct.

* output resistance

$\boxed{\text{case 1}}$ when $R_s = 0$, $V_\pi = -V_x$

$$-I_x + \frac{V_x}{R_E} + \frac{V_x}{r_o} + g_m V_x + \frac{V_x}{r_\pi} = 0$$

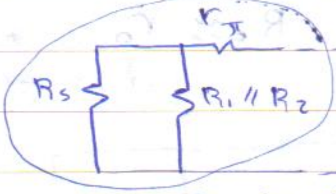
$$R_o = \frac{V_x}{I_x} \quad , \quad \frac{1}{R_o} = \frac{I_x}{V_x}$$

$$\frac{I_x}{V_x} = \frac{1}{R_E} + \frac{1}{r_o} + \left(g_m + \frac{1}{r_\pi}\right) \rightarrow \frac{1 + g_m r_\pi}{r_\pi} \rightarrow \frac{1+\beta}{r_\pi}$$

$$R_o = \frac{V_x}{I_x} = R_E // r_o // \frac{r_\pi}{1+\beta} \approx \frac{r_\pi}{1+\beta}$$

* considered very small. (10's of Ω)

$\boxed{\text{case 2}}$ $R_s \neq 0$



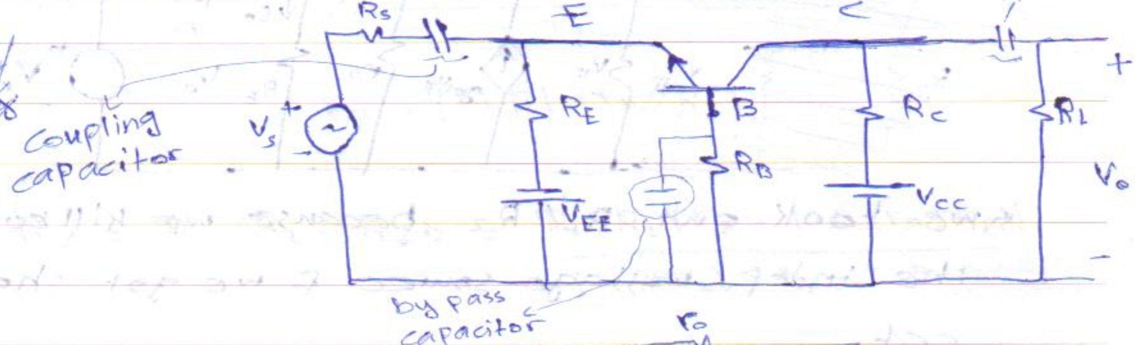
$r_\pi + R_s // R_1 // R_2$

$R_s < R_1 // R_2$

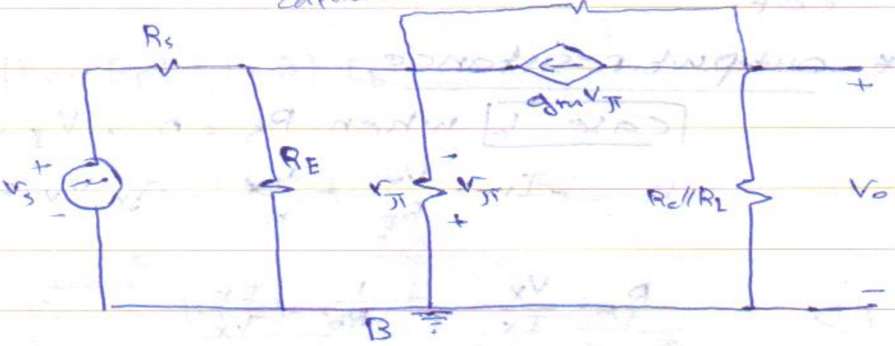
$$R_o = R_E // r_o // \frac{r_\pi + R_s // R_1 // R_2}{1+\beta}$$

$$\approx \frac{r_\pi + R_s}{1+\beta}$$ remember this

* the common - Base configuration



~~* capacitive coupling~~



* it can be shown that

$A_v = g_m R_C // R_L$

$A_i = \frac{\beta}{1+\beta} = \alpha < 1$ * no current gain

$R_{in} \simeq \frac{r_\pi}{1+\beta}$ * considered very small.

$R_o \simeq r_o$ * considered very high.

where is ro !!

* study the book.

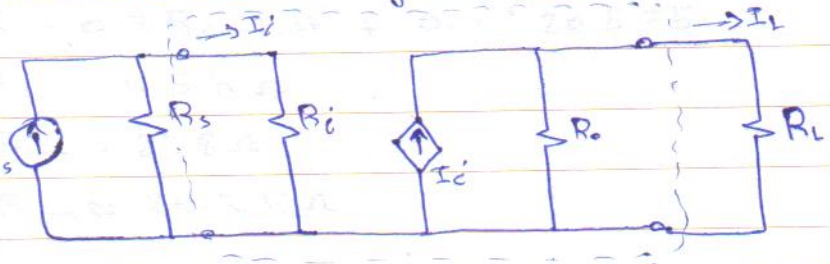
* summary of the configuration

	A_v	A_i	R_i	R_o
CE	yes >1	yes >1	moderate & high with R_E	moderate
~~CE~~ CC	No <1	yes >1	high	very small
CB	yes >1	No <1	very small	high

* Voltage & current buffers
  * since the ~~CE~~ CC amp. has very high input resistance & very low output resistance & $A_v = 1$. it acts as a voltage buffer.

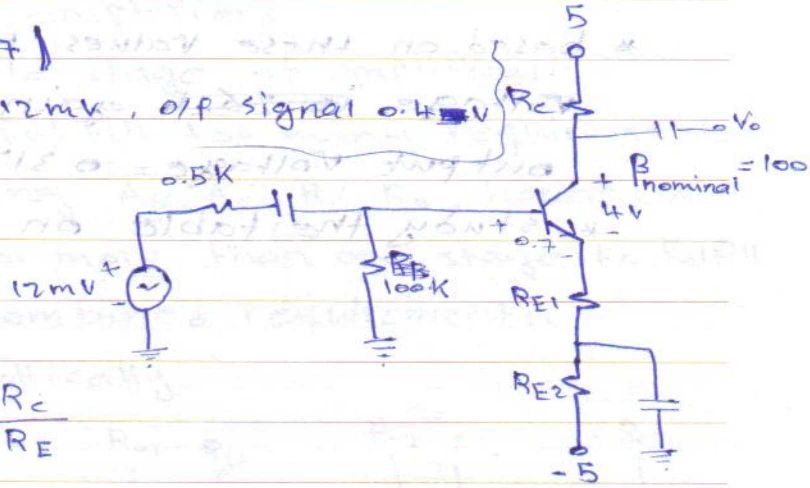
  * " ... CB ... has ~~ver~~ low input ... & very high output ..... & $A_i = 1$ ..... as a current buffer.

ex: Consider the following cct.



determine conditions to get max. I_L current ex: 6.7 (P407)

i/p signal 12mV, o/p signal 0.4 V



let's use $A_V = \frac{-R_c}{R_E}$

$$|A_V| = \frac{R_c}{R_E} = \frac{0.4}{0.012} = 33.\bar{3}$$

since $\frac{R_c}{R_E}$ is a not very accurate gain (~~grade~~ crade) choose $\frac{R_c}{R_E} = 40$

let $I_E = I_C = 0.2\,mA \Rightarrow I_B = \frac{0.2}{101}\,mA$

$$100 * \frac{0.2}{101} + 0.7 + 0.2\,(R_{E1} + R_{E2}) = 5$$

$$\Rightarrow R_{E1} + R_{E2} = 20.5\,K\Omega$$

$$A_V = 40 = \frac{R_c}{R_{E1}}$$

$$-5 + 0.2 R_c + 4 + 0.2 * 20.5 = 5$$

$R_c = 9.5\,K\Omega$

$R_{E1} = 238\,\Omega$

$R_{E2} \simeq 20.3\,K\Omega$

choose standard values ⇒ 9.5 → 10K
238 → 240Ω
20.3 → 20K

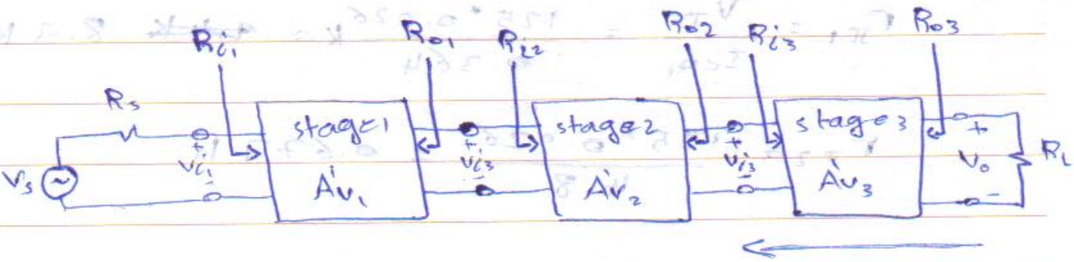
* based on these values the measured output voltage ~~is 26.4~~ gain is 26.4 (≠ 33.3)

output voltage = 0.317V (≠ 0.4)

* study the table on p 409

* multistage amplifiers

- * a single stage of amplification cant fulfill too many requirements regarding A_v, A_i, R_i, R_o, hence, a need for more than one stage to fulfill the combined requirements.
- * schematically



$$V_o = \frac{R_L}{R_L+R_{o3}} A'_{v_3} \underset{\sim}{V_{i3}}, \quad \underset{\sim}{V_{i3}} = \frac{R_{i3}}{R_{i3}+R_{o2}} A'_{v_2} \underset{\sim}{V_{i2}}, \quad \underset{\sim}{V_{i2}} = \frac{R_{i2}}{R_{i2}+R_{o1}} A'_{v_1} \underset{\sim}{v_{i1}}, \quad \underset{\sim}{v_{i1}} = \frac{R_{i1}}{R_{i1}+R_s} V_s$$

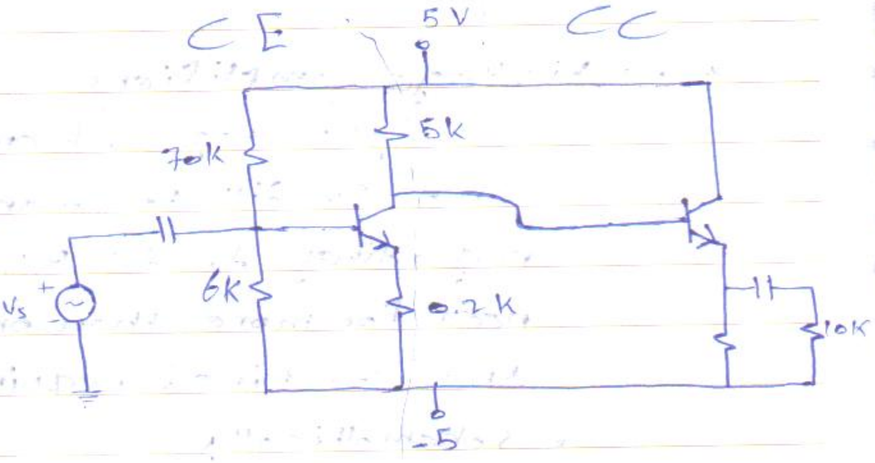
* electronics 2.

* amplifiers.

- where A'_{v_i} is defined as $\frac{V_{oi}}{V_{ii}}$ & not as $\frac{V_{oi}}{V_{is}}$

ghzawi

Past



$$r_{\pi 1} = \frac{V_T}{I_{CQ_1}} = \frac{125 * 0.026}{0.364} K = \cancel{4.4\,K}\ 8.9\,K$$

$$r_{\pi 2} = \frac{125 * 0.026}{4.8} = 0.677\,K$$

Amplifiers

NoteBook

By: Ahmad Ghzawi
Dr. Omar Ghzawi

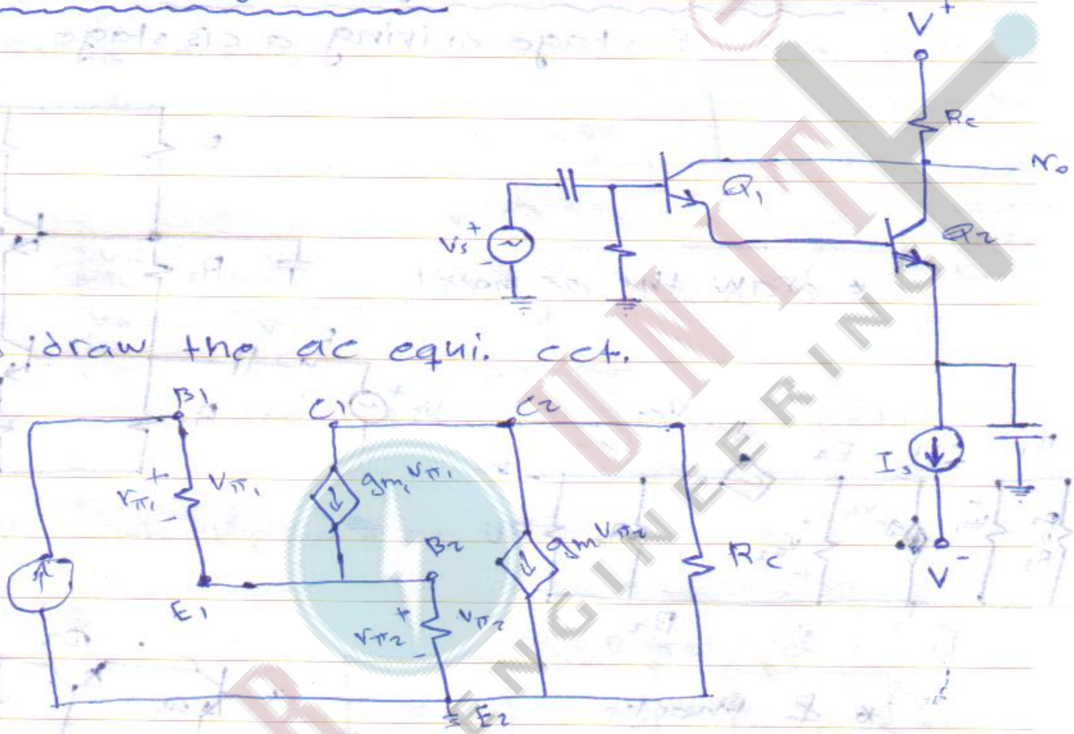
بأفكارنا_نُبدع

4th & 5th Weeks

14/7/14 Mon.

* The Darlington Pair

* draw the ac equi. cct.



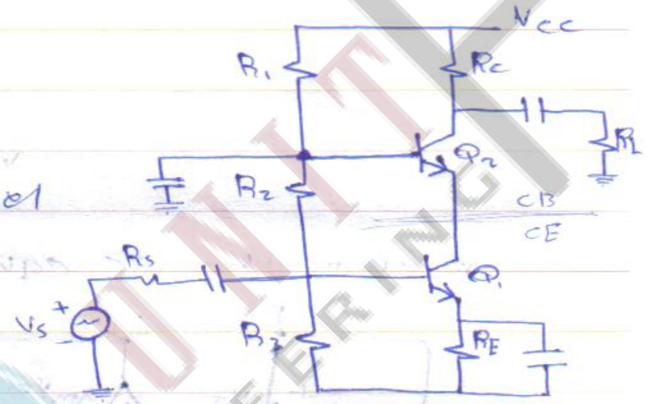
* & study the gains & resistances

$A_i \simeq \beta_1 \beta_2$

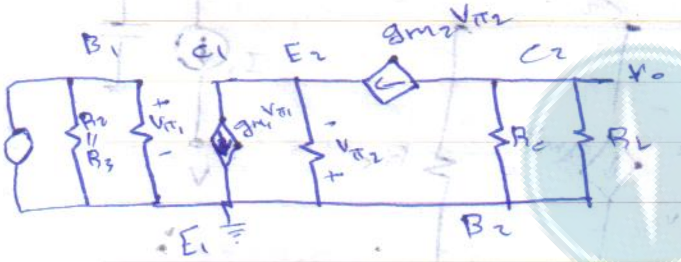
$R_i \simeq 2\beta_1 r_{\pi_2}$

* The Cascode ~~stag~~ Amplifier

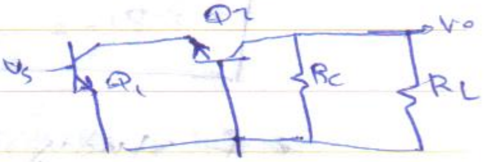
* A CE stage driving a CB stage



* draw the ac model

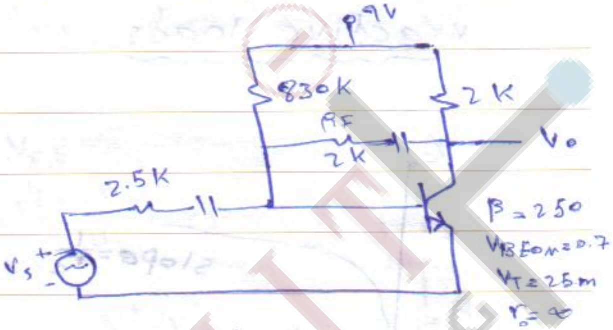


* & that



$$A_V = -g_{m1}(R_C // R_L)$$

* ex: past papers, for the first exam



$-9 + 830 I_B + 0.7 = 0$

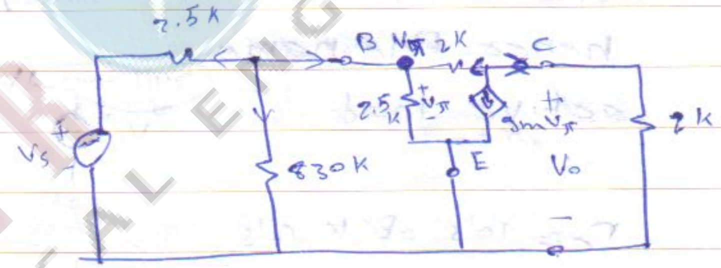
$I_B = 10\ \mu A$

$I_C = 2.5\ mA$

$r_\pi = \frac{\cancel{I_B}\,V_T}{\cancel{V_T}\,I_B} = \frac{\beta \cancel{I_C}\,V_T}{\cancel{V_T}\,I_C} = \cancel{0.1m} = 2.5\ K\Omega$

$g_m = \frac{I_C}{V_T} = 100\ mA/V$ / $\beta = r_\pi g_m \rightarrow g_m = 100\ mA/V$

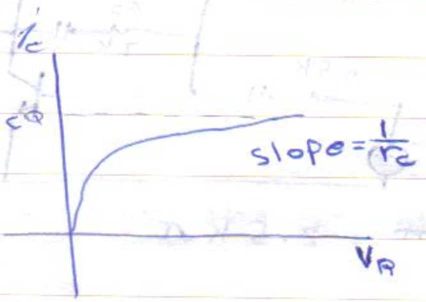
* $V_{CE} = 9 - 2K * 2.5m = 4V$

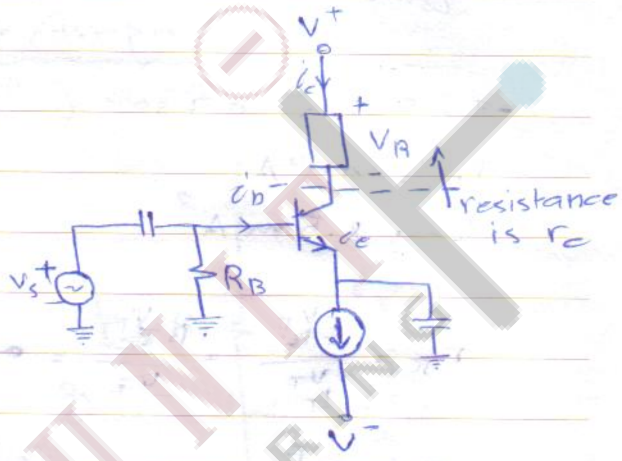


$\cancel{R_o}\ \frac{V_o}{R_C} + g_m V_\pi + \frac{V_o - V_\pi}{R_F} = 0$

$\frac{V_\pi - V_s}{2.5k} + \frac{V_\pi}{830k} + \frac{V_\pi}{2.5k} + \frac{V_\pi - V_o}{R_F} = 0$

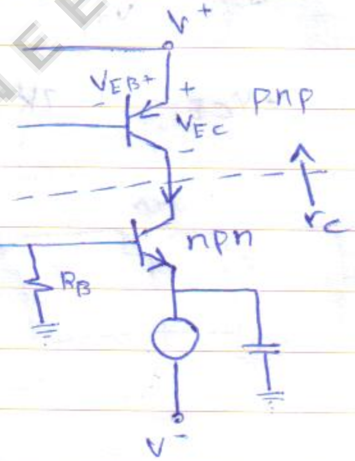
* active loads





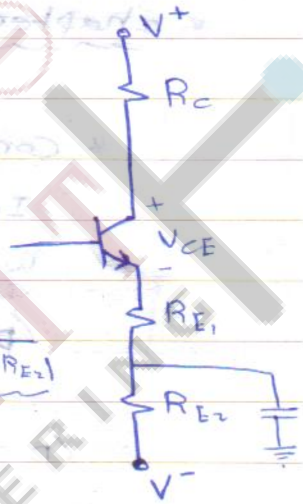
* the active load device (transistor) implements the load (collector resistance) hence the name active load

$r_c \approx$ 10's of kΩ's



* it can be shown that $A_v = -g_m r_c$

* Consider the following cct.

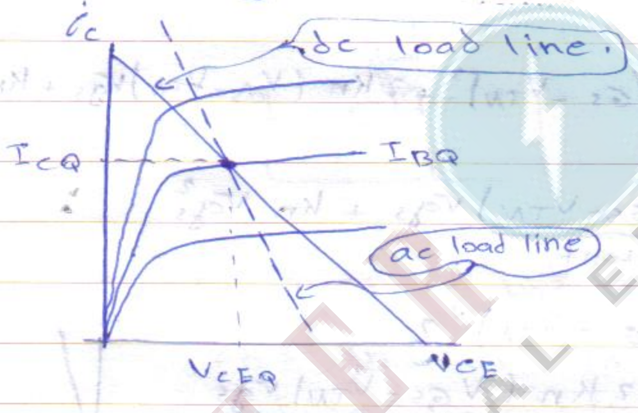


dc analysis

$$V^+ - V^- = R_C I_{CQ} + V_{CE} + (R_{E_1} + R_{E_2})\left(\frac{1+\beta}{\beta}\right) I_{CQ}$$

$$I_{CQ} = -\frac{V_{CE}}{R_C + \frac{1+\beta}{\beta}(R_{E_1}+R_{E_2})} + \underbrace{\frac{V^+ - V^-}{R_C + \frac{1+\beta}{\beta}(R_{E_1}+R_{E_2})}}$$

$$y = m_1 \overset{V_{CE}}{x} + c$$



ac analysis

$$R_C i_c + v_{ce} + R_{E_1} i_e = 0$$

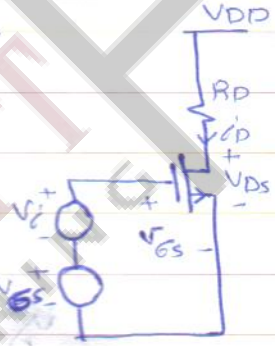
& let $i_e = i_c$

$$i_c = -\frac{1}{R_C + R_{E_1}} v_{ce}$$

amplifiers 2017/14 Jun.

* chapter 4 : MOSFET Amplifiers.

* consider the following cct.



$I_D = k_n (V_{GS} - V_{TN})^2$

with input signal v_i

$i_D = k_n (v_{GS} - V_{TN})^2$

$i_D = k_n (V_{GS} + \underbrace{v_i}_{= v_{gs}} - V_{TN})^2$

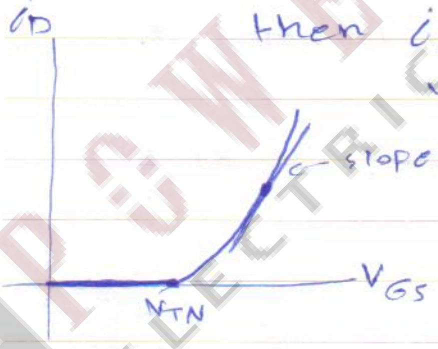
$I_{DQ} + i_d = k_n (V_{GS} - V_{TN})^2 + 2 k_n (V_{GS} - V_{TN}) v_{gs} + k_n v_{gs}^2$

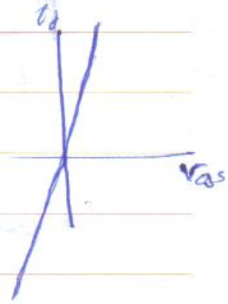
$i_d = \underbrace{2 k_n (V_{GS} - V_{TN})}_{\text{constant}} v_{gs} + k_n v_{gs}^2$

* if $v_{gs} \ll (V_{GS} - V_{TN}) * 2$

then $i_d = 2 k_n (V_{GS} - V_{TN}) v_{gs}$

$y = m \quad x$





* define $g_m = \frac{i_d}{v_{gs}} = 2 k_n (V_{GS} - V_{TN}$

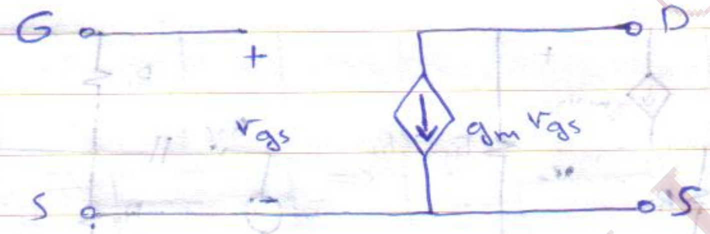
* $g_m = \frac{\partial i_D}{\partial v_{GS}} \Big|_{V_{GSQ}}$

* it can be shown that

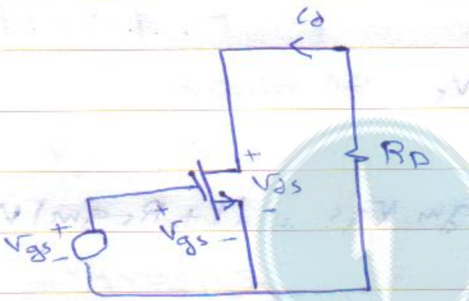
$g_m = \sqrt{k_n I_{DQ}}$

$\underbrace{12 \; 14}_{30} \; 4 \; \underbrace{13 \; 10}_{} \; 6$ ⑤⑨ + 19 + 16 + 4 (57) (59) (98)

* the model so far is



*

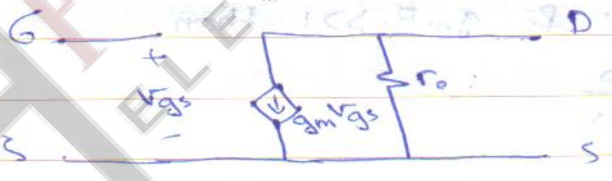


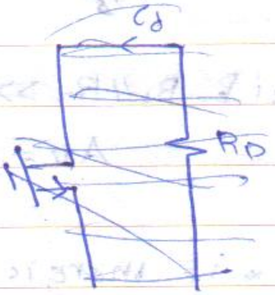
* to improve the model use

$$i_D = K_n (V_{GS} - V_{TN})^2 (1 + \lambda V_{DS})$$

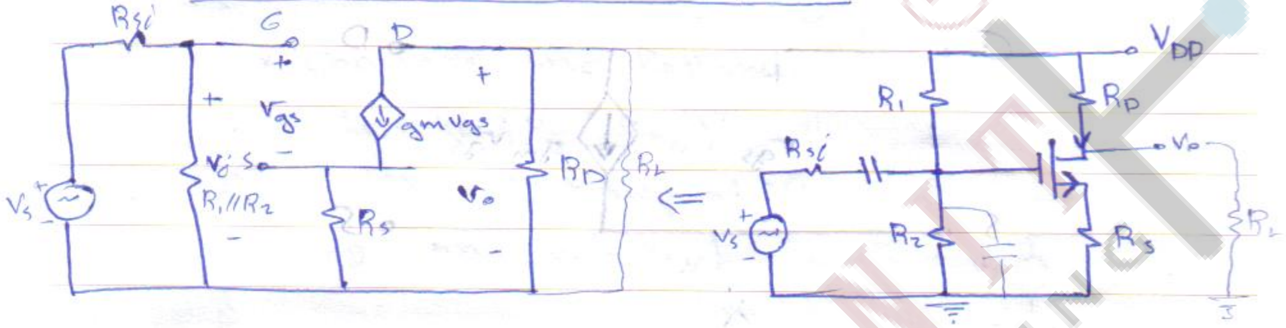
define $r_o = \frac{\partial i_D}{\partial v_{DS}}\Big|_{V_{GSQ}}$

$$r_o = \frac{1}{\lambda I_{DQ}}$$





* the common source amplifier



$$v_i = \frac{R_1 // R_2}{R_1 // R_2 + R_{si}} V_s$$

$$= v_{gs} + R_s g_m v_{gs} = (1 + R_s g_m) v_{gs}$$

$$v_{gs} = \frac{1}{1 + g_m R_s} v_i$$

$$V_o = - g_m v_{gs} R_D$$

$$= - g_m R_D \frac{1}{1 + g_m R_s} v_i = \frac{-g_m R_D}{1 + g_m R_s} \frac{R_1 // R_2}{R_1 // R_2 + R_{si}} V_s$$

$$A_v = \frac{V_o}{V_s} = \frac{-g_m R_D}{1 + g_m R_s} \frac{R_1 // R_2}{R_1 // R_2 + R_{si}}$$

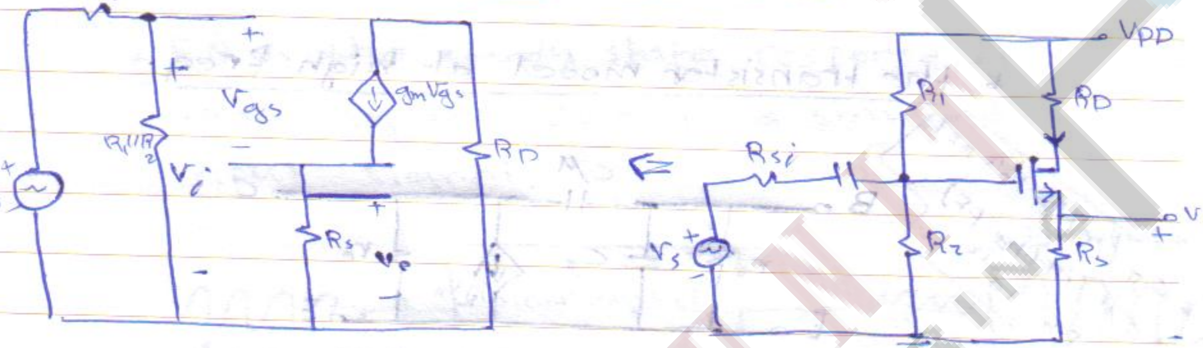
* if $R_1 // R_2 >> R_{si}$ & $g_m R_s >> 1$ then.

$$A_v = \frac{-R_D}{R_s}$$

* if there is R_L, just make every $R_D = R_D // R_L$

* to increase the gain. we use by pass cap. & it wont affect the dc analysis.

* the common drain amplifier



$v_i = v_{gs} + g_m v_{gs} R_s = (1 + g_m R_s) v_{gs}$

$v_{gs} = \frac{1}{1 + g_m R_s} v_i$, $v_i = \frac{R_1 // R_2}{R_1 // R_2 + R_{si}} v_s$

$v_o = g_m v_{gs} R_s = \frac{g_m R_s}{1 + g_m R_s} v_i$

so $A_v = \frac{v_o}{v_s} = \underbrace{\frac{g_m R_s}{1 + g_m R_s}}_{<1} \underbrace{\frac{R_1 // R_2}{R_1 // R_2 + R_{si}}}_{<1} < 1$

*no voltage gain

* if $R_L \Rightarrow R_s = R_s // R_L$

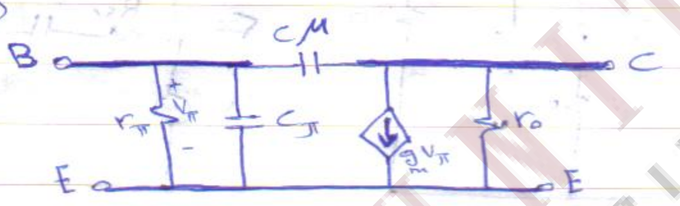
amplifiers 22/7/14 tues.

* chapter 7 : frequency response & amplifiers

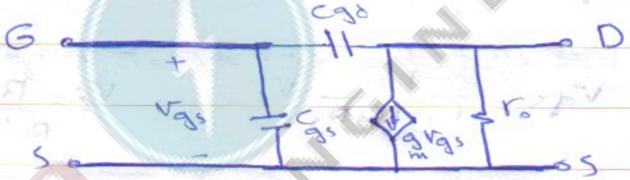
* the transistor model at high freq.

- * C_π (in the 10's pF)
- * C_μ (in the pF)

$pF = 10^{-12}$



* NPN BJT HF model.



* n-MOS HF model.

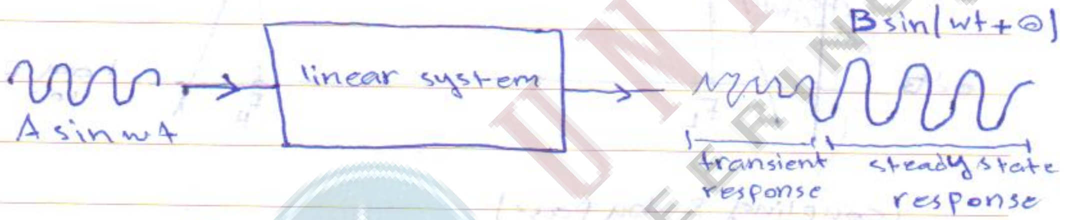
- * the behavior of the transistor depends on the freq. of the input signal.
- * the behavior of the amplifier cct. also depends on the external capacitances (coupling & by pass capacitors)

amplifiers

23/7/14 thurs.

* Definition of frequency response (FR)

* FR is the steady state response of a linear system due to a sinusoidal input signal.

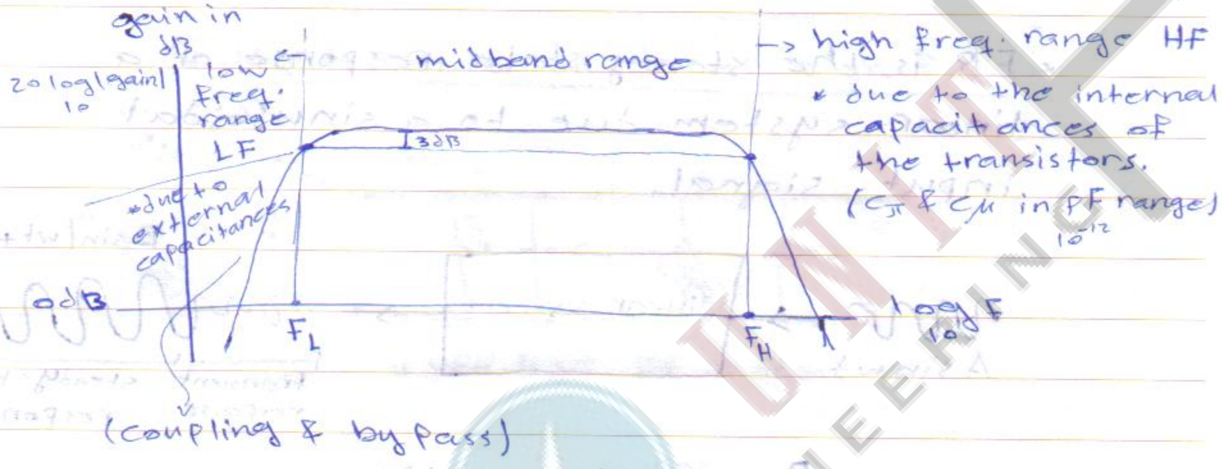


* gain = $\frac{B}{A}$, Phase shift = θ

amplifiers

24/7/14

* Bode plots



POWER UNIT

Electronics II

NoteBook

Dr. Omar Ghzawi

By: Ahmad Ghzawi

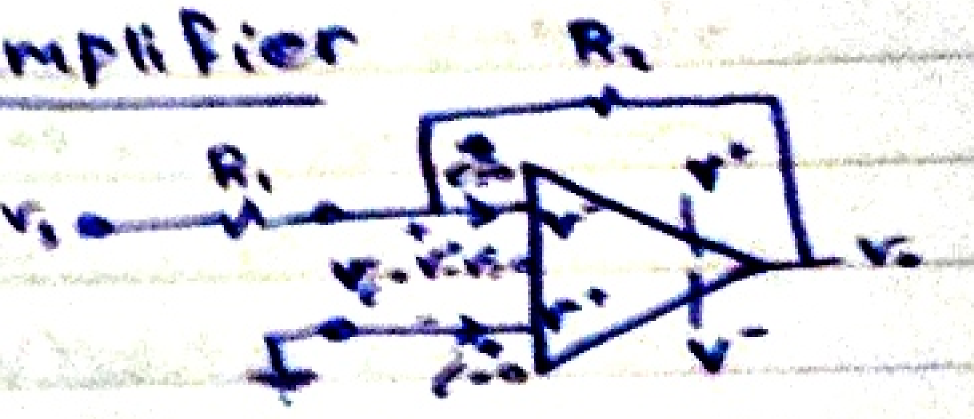
بأفكارنا_نُبدع

amplifiers

27
10/8/14 sun.

- **Op-Amp circuits** (ccts involving op-amps)
  - proved using the ideal model.

- **the inverting amplifier**



$$\frac{v_s - v^-}{R_1} = i^- + \frac{v^- - v_o}{R_2}$$

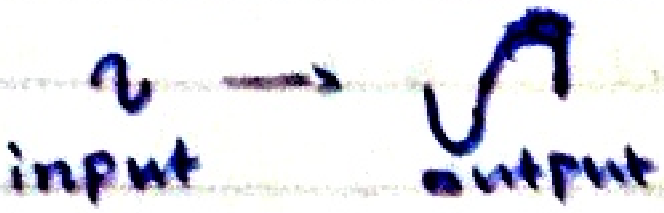
also $v^+ - v^- = 0$

$v^+ = 0$ so $v^- = 0$ V & $i^- = 0$, $i^+ = 0$

hence $\frac{v_s}{R_1} = \frac{-v_o}{R_2}$

- the (-) means

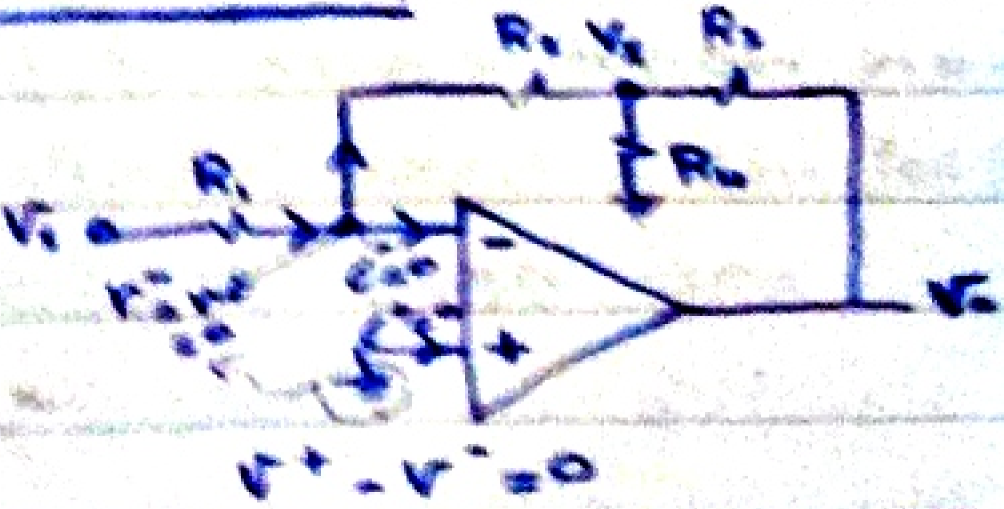
$\frac{v_o}{v_s} = \frac{-R_2}{R_1}$



- generally $\frac{v_o}{v_s} = \frac{-Z_2}{Z_1}$

- the input resistance of this cct. is **R₁** (considered a disadvantage).

- to get a high input resistance (R_i) for the inverting amp. together with high gain yet using a moderate R_2 resistance we use the following cct.
  the T-network amp.



$v^+ - v^- = 0$

$v^+ = v^-$

amplifiers

11/8/14 Mon

$$\frac{V_s - 0}{R_1} = \frac{0 - V_x}{R_2} \Rightarrow \frac{V_x}{V_s} = \frac{-R_2}{R_1}$$

$$-\left(\frac{0 - V_x}{R_2}\right) + \frac{V_x}{R_4} + \frac{V_x - V_o}{R_3} = 0 \Rightarrow \frac{V_o}{V_x} = R_3\left[\frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4}\right]$$

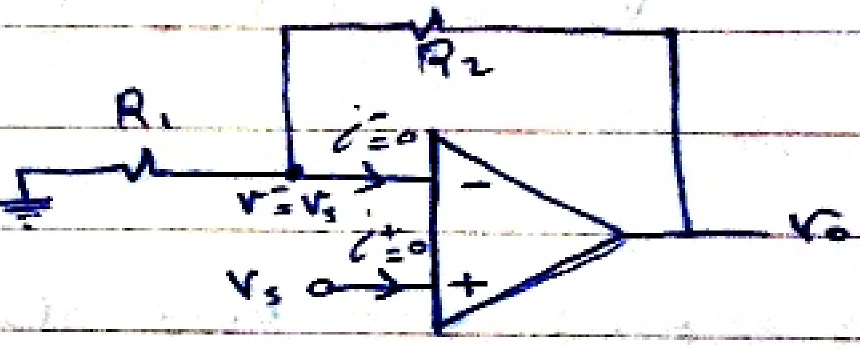
$$= 1 + \frac{R_3}{R_2} + \frac{R_3}{R_4}$$

So $$\frac{V_o}{V_s} = \frac{-R_2}{R_1}\left[1 + \frac{R_3}{R_2} + \frac{R_3}{R_4}\right]$$

- the input resistance of the amp. = ∞
- " " " of this cct. ≈ R_1

- <u>the non-inverting amplifier</u>

$$\frac{0 - V_s}{R_1} = \frac{V_s - V_o}{R_2} + \overset{\textcircled{i^-}}{0}$$



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

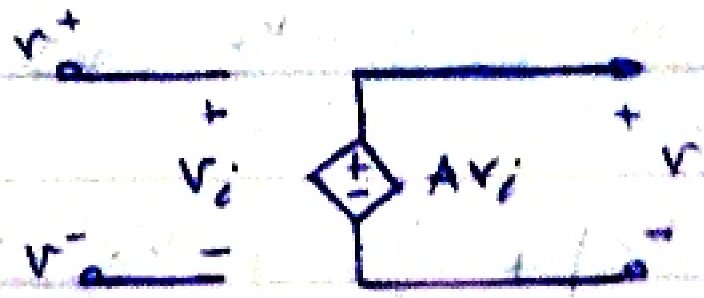
$v^+ = v^- = V_s$

$$\frac{V_o}{V_s} = \left(1 + \frac{R_2}{R_1}\right) > 1$$

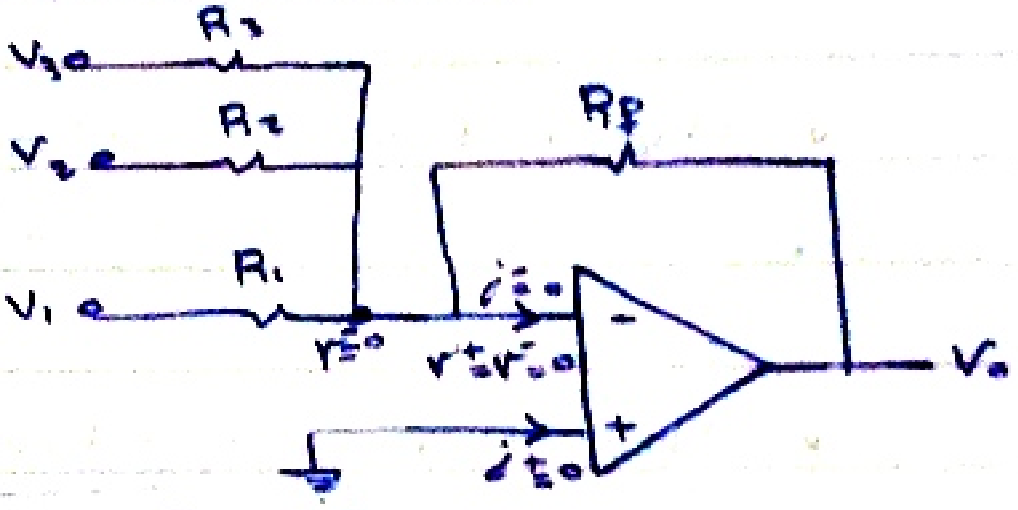
- it can be shown that the input resistance for this cct. is very larg, & the output resistance is very small.
- prove these facts.
- voltage buffer: the gain is $\underline{1}$ if $R_1 = \infty$ or $R_2 = 0$ or $R_1 = \infty$ & $R_2 = 0$

- determine R_i & R_o fo

* the model



* the summing amplifier

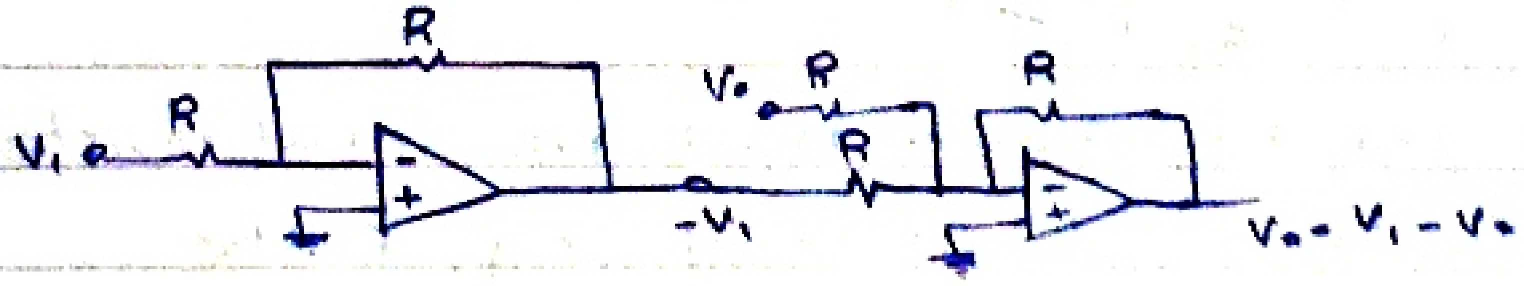


$$\frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3} = \frac{-V_o}{R_f}$$

$$V_o = -\left[\frac{R_f}{R_1} V_1 + \frac{R_f}{R_2} V_2 + \frac{R_f}{R_3} V_3\right]$$

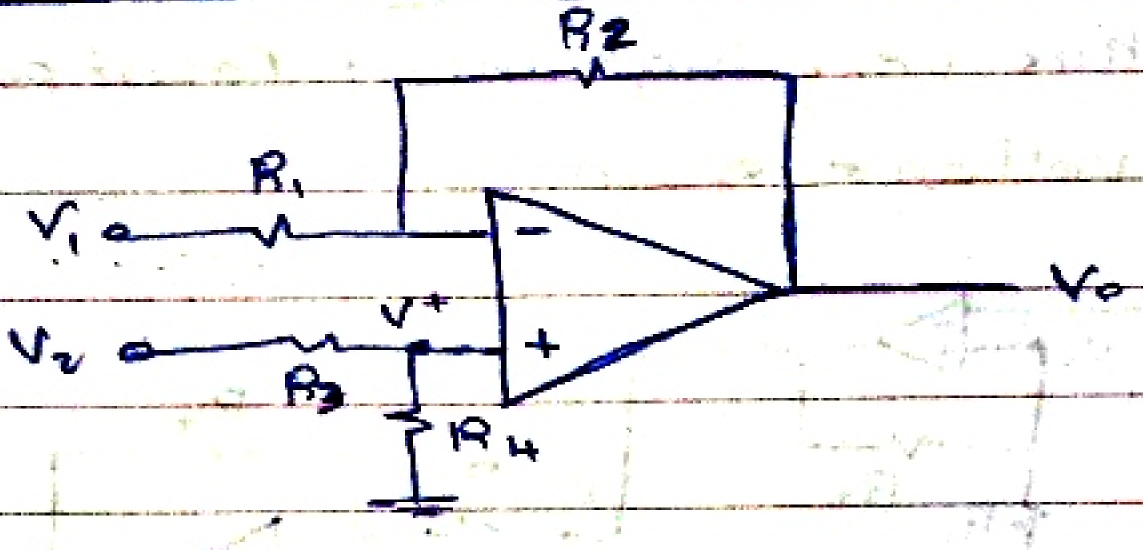
ex: use two op-amps to get $V_1 - V_2$

$$V_1 - V_2 = -(V_2 + (-V_1))$$



* instead of using two op-amps, we can use a signal op-amp resulting in a difference amplifier.

* the difference amplifier



$$v^+ = \frac{R_4}{R_4+R_3} V_2$$

* using superposition

let $V_2 = 0$

$$V_{o1} = \frac{-R_2}{R_1} V_1$$

(V_o due to V_1)

let $V_1 = 0$

$$V_{o2} = \left(1 + \frac{R_2}{R_1}\right) v^+ = \left(\frac{R_1+R_2}{R_1}\right)\left(\frac{R_4}{R_4+R_3}\right)V_2$$

$$V_o = V_{o2} + V_{o1} = \frac{R_1+R_2}{R_1}\,\frac{R_4}{R_4+R_3}V_2 - \frac{R_2}{R_1}V_1$$

$$\text{if } \frac{R_4}{R_3} = \frac{R_2}{R_1} \Rightarrow V_o = \frac{R_2}{R_1}(V_2 - V_1) = \frac{R_4}{R_3}(V_2 - V_1)$$

* if a common noise signal is present, then

$V_1' = V_1 + V_n$ & $V_2' = V_2 + V_n$

hence $V_o = \frac{R_2}{R_1}(V_2' - V_1') = \frac{R_2}{R_1}(V_2 + V_n - V_1 - V_n)$

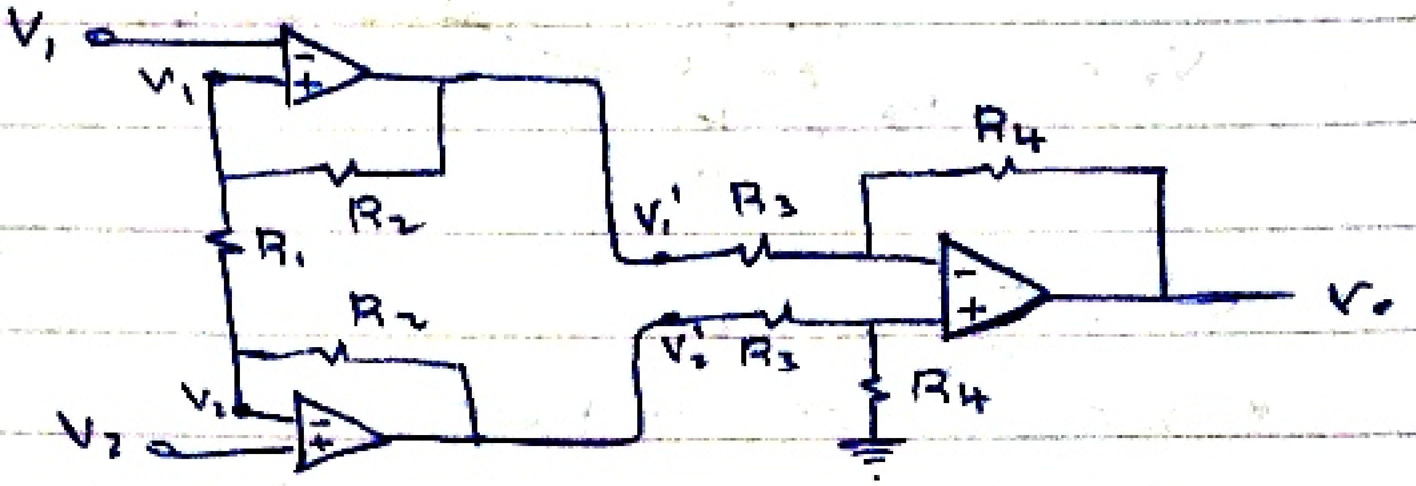
$= \frac{R_2}{R_1}(V_2 - V_1)$

i.e the common mode noise is cancelled out.

* it can be shown that the input resistance of this amp is approx. $2R_1$ (with justification)

* the instrumentation amp. (IA)

- I A has very high input resistance & high voltage gain.



$$V_o = \frac{R_4}{R_3}(V_2' - V_1')$$

$$V_2' - V_1' = i_2(R_2 + R_1 + R_2) = (R_1 + 2R_2)\frac{|V_2 - V_1|}{R_1}$$

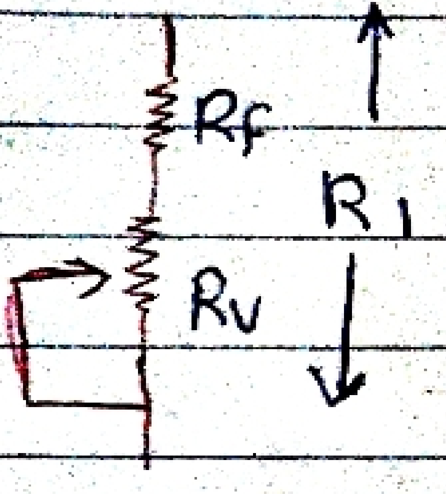
$$V_o = \frac{R_4}{R_3}\left(1 + \frac{2R_2}{R_1}\right)(V_2 - V_1)$$

* we chage R_1 to ---- (gain)

13-8-2014
Wednesday

PAGE
DATE

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



Example:- gain between $\overset{15}{\text{[illegible]}}$ - 805
lets $\frac{R_4}{R_3} = 5$, $\underline{R_V} = 50\,k\Omega$.

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

$$805 = 5\left(1+\frac{2R_2}{R_f}\right)$$

$$80R_f = R_2 \quad \text{----} ①$$

$$15 = 5\left(1+\frac{2R_2}{50+R_f}\right)$$

$$50+R_f = R_2 \quad \text{----} ②$$

So $R_f = \frac{50}{79}\,k\Omega$ & $R_2 = 80\left(\frac{50}{79}\right)k\Omega$
$= .633\,k\Omega$ $= 50.6\,k\Omega$

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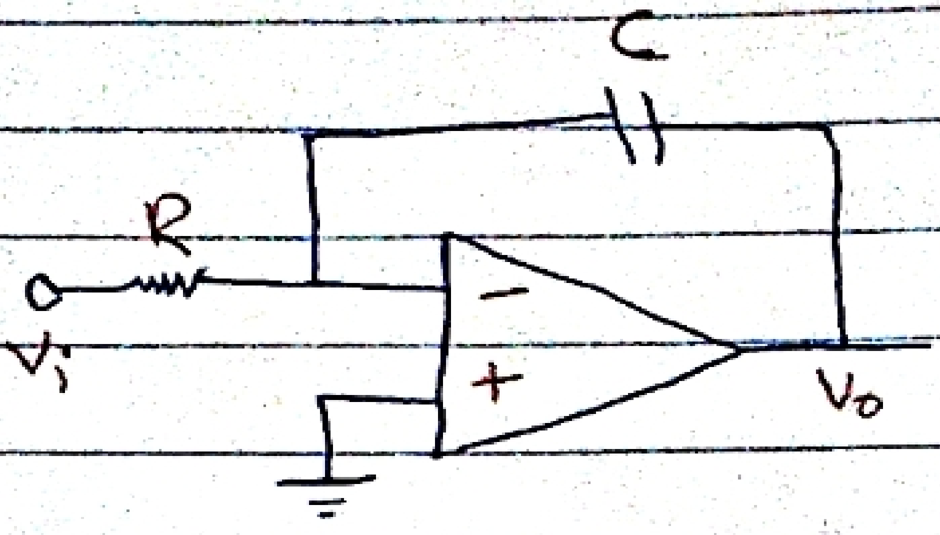
Integrating circuit.

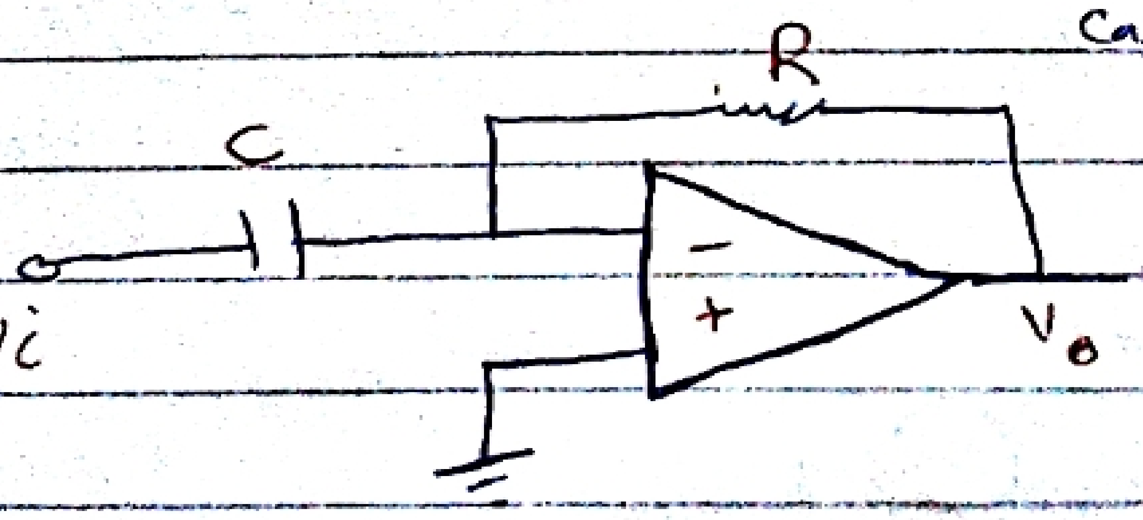


$$\frac{V_o}{V_i(s)} = \frac{-X_c}{R} = \frac{-Z_2}{Z_1} = -\frac{\frac{1}{sC}}{R}$$

$$V_o(s) = -\frac{1}{RC}\,\frac{1}{s}\,V_i(s)$$

$$\boxed{v_o(t) = \frac{1}{RC}\int v_i(t)\,dt}$$

Basic Differentiation circuit



يمكن استخدام ملف بدل من الـcapacitor
ولكن غير محبب استخدامه لأنه
١- ثقيل ٢- سعره غالي
٣- حجمه كبير.
لذلك يتم تبديل اماكن
R & C

$$\frac{V_o(s)}{V_i(s)} = -\frac{Z_2(s)}{Z_1(s)} = -\frac{R}{\frac{1}{sC}}$$

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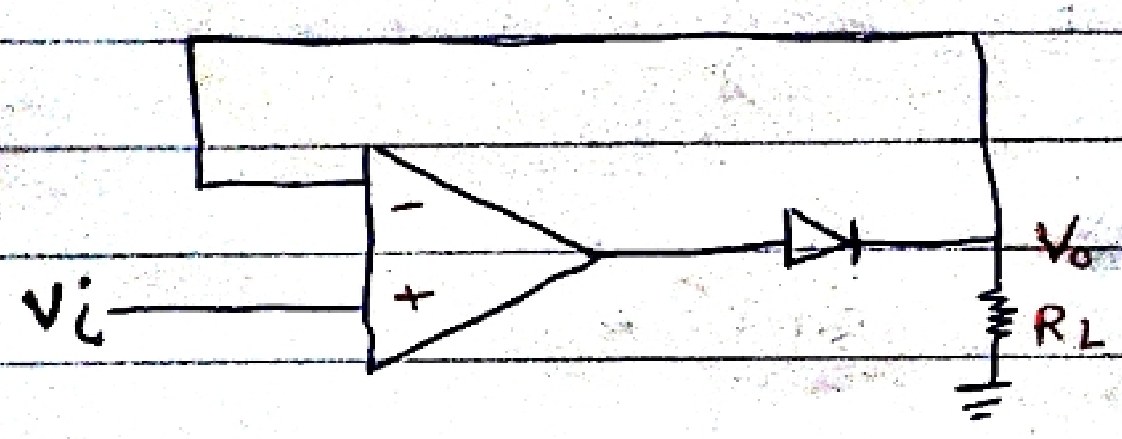
13-8-2014

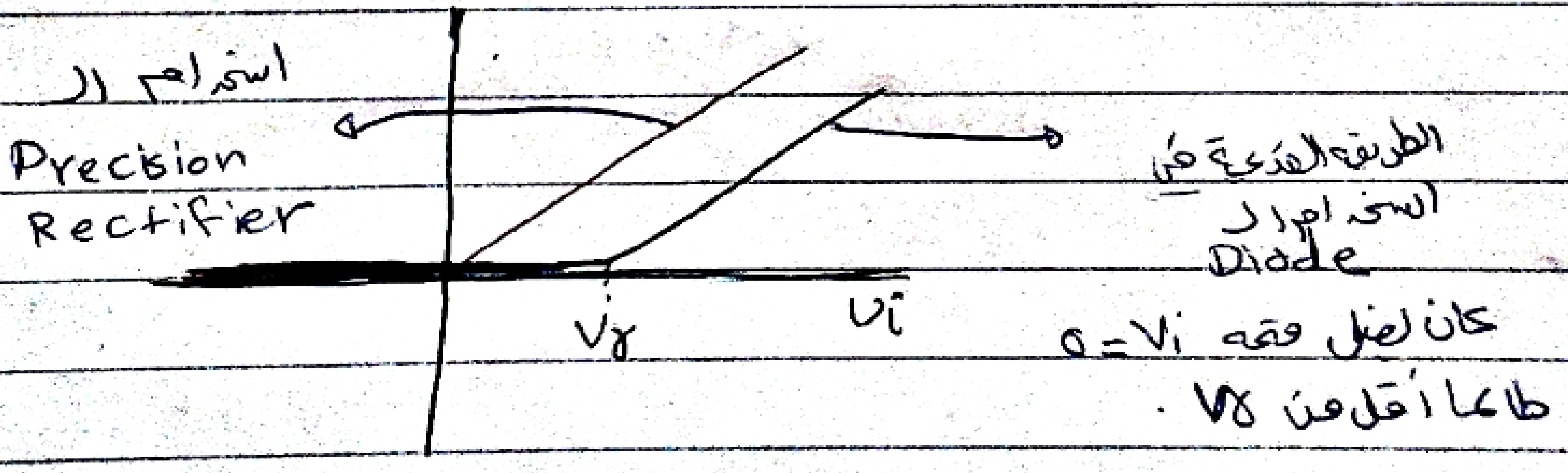
$= -RCS$

$V_o(s) = -RC\,s\,V_i(s)$

$$\boxed{V_o(t) = -RC\frac{dv_i(t)}{dt}}$$

Precision Rectifier





① no waste of Vγ ② and works even when $V_i < V_\gamma$

عدم استخدام precision Rectifier واستخدام الـ Diode العادي بسبب السعر
(Power supply)

wednesday

13 - 8 - 2014

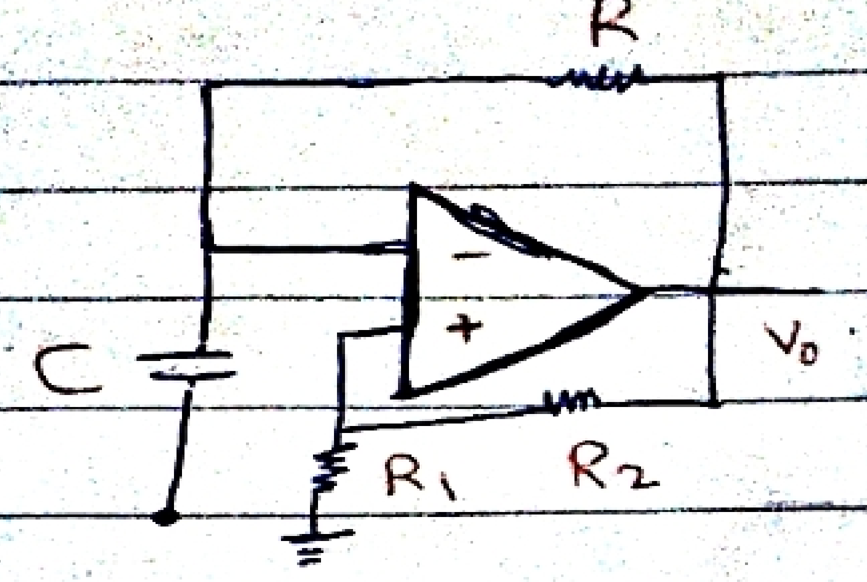
101 — 105

قاعات الامتحان

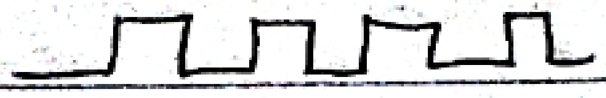
من

105 ← [illegible]

Square wave generater.



there is no Vi
in this op-Amp.

generate square - wave 

$$T = 2RC \ln \frac{1+\lambda}{1-\lambda}$$

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

The End of
The lec: