L1: Electronics: Introduction to Semiconductor :- (3-6-2020)
and Semiconductor Diodes:-

* Electronics Circuits:-

نصادفنا بحياتنا اليومية في جميع الأجهزة والمعدات الصناعية ومن هنا تنبع أهميتها ، مثلاً فالـ mother board لازم نعرف نتعامل معها كـ analysis/ design ، ولازم أعرف شو الفرق بينها وبين الـ Circuits فهي أعطتني tools تحكي كلل الدوائر الكهربائية أو ديزاين ، التي كان في تركيبتها inductor/ Resistance/ Voltage Source/ Capacitor ، وتعلمنا CH-1 طرق التحليل للسيركت ، راح نرجع نستخدمها .

* Electronics Devices:-

→ Diodes:- (ثنائي القطبية) 2-terminal device ⇆ مدخل ومخرج / مدخلين / مخرجين

2 Kinds:-

1. Rectifier diode.
2. Zener diode.
3. Light Emitting Diode (LED). باعث ضوئي (عنيرهم كثير)

→ Transistors:- (ناقل)

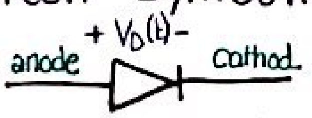
1. Bipolar Junction transistor. (BJT). (تقاطع القطبين)
2. Field Effect Transistor (FET)

→ Integrated Circuits:- (IC) (تقوم بعمل Function معينة)
Voltage regulator/ amplifier ①② كـ
لفوت بتصميها Transistor/ Diodes

* Diodes:-

هي عبارة عن electronic device في تركيبتها شيء يسمى p-n Junction .

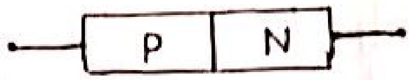
→ Circuit Symbol:-



$i_D(t)$ ⟶ وممكن نعبر التيار بهذا الاتجاه.

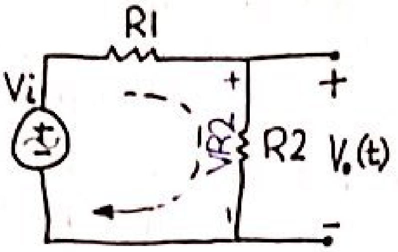
* ملاحظات:
1. لا يعبر من الشمال لليمين ولكن يعبر من الـ anode للـ Cathode .
2. ممكن أن يعبر بالظروف الملائمة .
3. ستحكي بالاتجاه العكسي ما مريتا رح نفهم دقة الملاحظة.
4. اللون الفضي هو الـ Cathode أو نحمل انتباه.

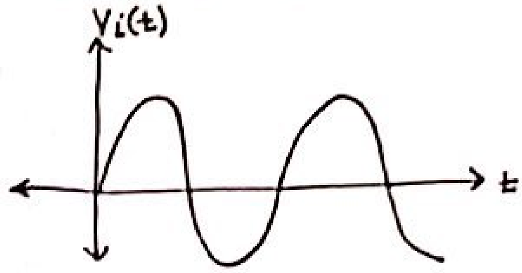
→ Physical Construction:-



2 layers from P and N material.

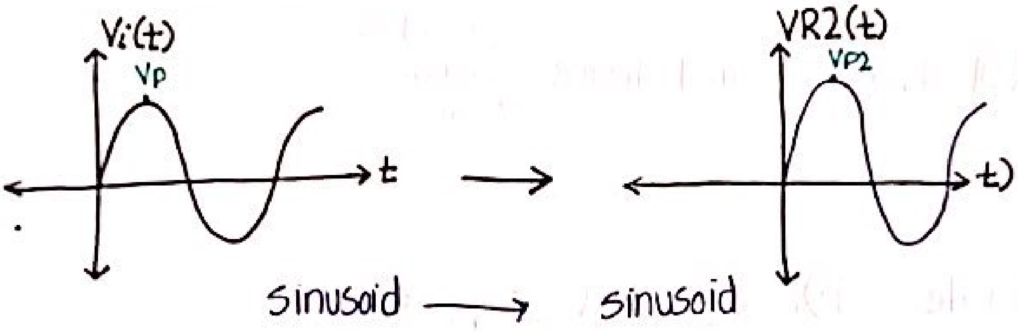
→ Start to Understand what is the different between resistor and diodes:-





- I need to find the volt. on R2:-

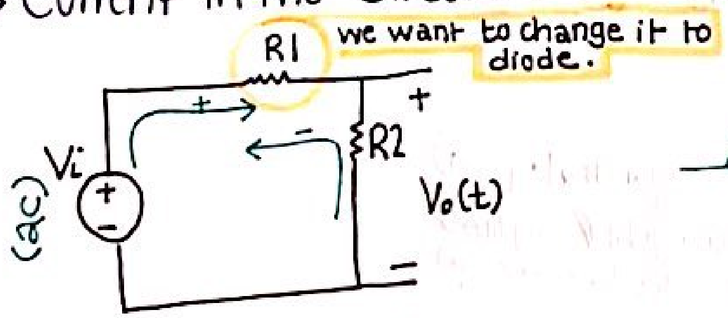
$$VR2 = \frac{R2}{R1+R2} \cdot V_i$$



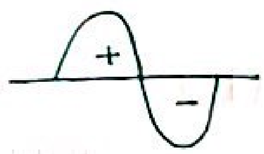
- Suppose $R_1 = R_2$

$V_{P2} = \frac{V_P}{2}$

→ Current in the Circuit:-

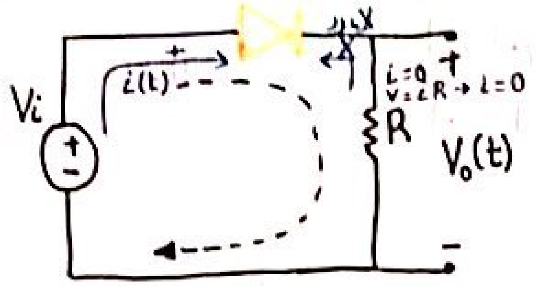


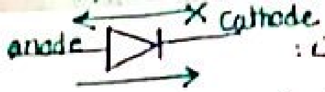
sinusoid - Voltage.



- we have to directions for the currents which dependens on the sinusoid voltage source.

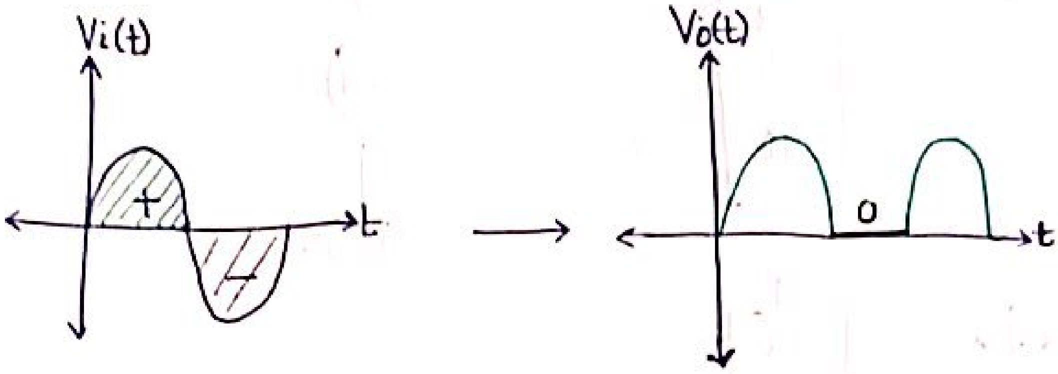
- ac-Voltage Leads to ac-current.
- Resistor allow the currents to through it from Left to Right or vice versa.





*ملاحظات:

1. الـ Diode يمكن أن يمر تيار من الـ anode للـ Cathode ولكن العكس لا.
2. وهنا يعني أنه سيمرر تيار فقط الـ positive half Cycle.



* Semi-Conductors:- كلهم Transistor/ IC / Diodes حكينا [1] مصنوعين منه.

Silicon Crystal at zero degree like insulator there is no Free electrons.

[2] لها خصائص معينة في الـ conductive للـ electrical current وتصنف المواد لثلاثة أنواع بناء عليه.

a: Conductor (R↓) b: Insulator (R↑↑)

c: Semiconductor (أضعف من الـ Insulator وأكبر من الـ conductor)

مثال عليه: السيليكون العدد الذري = 14.

[3] الـ materials مكونة من عدة مكونات

a: electrones(−) موزع في الـ orbits b: nutrones(0) c: protones(+) وجودهم في النواة

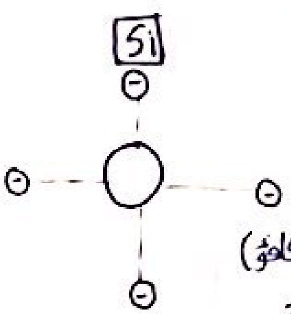
والذرة تكون balance أي غير مشحونة.

[4] توزع الإلكترونات حسب المعادلة $[2n^2]$ where n #of orbit.

2, 8, 18, 32 ----

Si العدد الذري 14 ← 2, 8, [4]

اسمهم Valance electrones (الإلكترونات التكافؤ) موجودين في المدار الأخير والنواة قادرة على جذبهم وليسو Free ماشيين يشاركو 3. روابط إلكترونية.



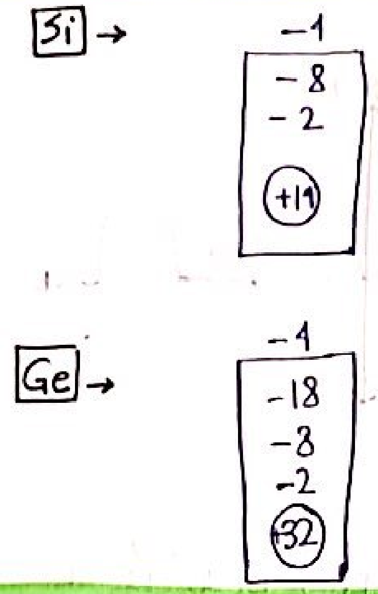
Ge/Si هم الـ Semi conductors فالمدار الأخير لهم 4 إلكترونات.

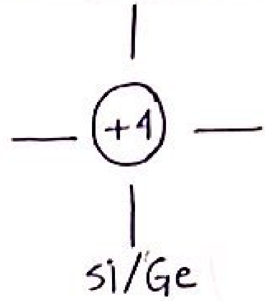
Ge العدد الذري = 32

التوزيع الإلكتروني: 2, 8, 18, [4]

مجموعة ذرات من نفس الـ material.

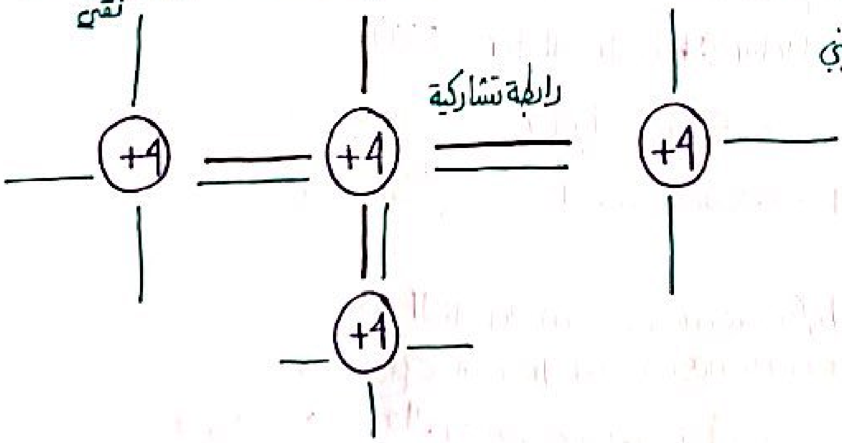
لتسهيل الرسم





* Covalent - Band:- رابطة تشاركية

in Intrinsic Silicon Crystal:-



1. هيك بتكون أي Crystal سليكون نقي ومتعادل لانو السليكون بالأصل متعادل.

2. وهاد بحصل عند degree 0C° يكون الـ material بحالة خمول والذرة متعادلة كليًا.

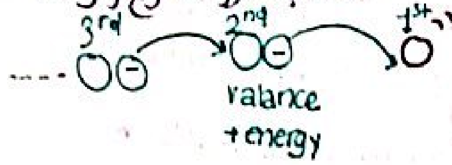
* What Will happen when we change the temperature?

الإلكترونات ما معهم طاقة تتجاوز المدار تاعهم وهي ممكن يوخذوها من الحرارة والذي سيحصل بعض الإلكترونات ستترك مكانها وصار مكانه فراغ أي (Hole) ولهيك اسم الإلكترون المتروك (Free electrons) فإذا صار فاقد الإنيرجي تاعته وشاف مكان فاضي رح يرجع يعبي الـ (Hole) واسمها (Recombanation) وهساعد الـ (holes) بساوي عدد الـ (Free electrones) ما زالو متواجدين فالـ (material) والشحنة متعادلة، حركة الإلكترونات عشوائية ولا تشكل تيار وما علاقة conduction لأنه فقط التيار المنظمة هي التي تشكل ذلك.

ملاحظة:- في درجة حرارة الغرفة (25°-27°) في عنا 1 broken bond لـ 3×10^{12} atoms يعني قليل جداً.

* Hole motion:-

هنا الإلكترون خرج وترك مكان ....⊖ Free electrone.



- (Holes) يمين ← شمال
- (Electrones) لليمين ← شمال

هون رح نحكي عن
hole currents
electrones currents.

* Energy Gap:-

1. insulator: عنده Valance electrones في المدار الأخير لتتحرر من المدار لازمهم energy Gap كمية معينة.

Valance Band → (EG) Conduction Band

كثير كفاية لتنقل وهو كبير 5eV وصعب تحمل عليها الـ material بدون ما تغير خصائصه.

2. Conductor: الـ Valance Band والـ Conduction Band في بينهم Overlap وفي بعض الـ material (Free electrones).

3. Semi-Conductor: حسب الـ material إله Gap فيه (EG) وما فيه Overlap.

EXP:

1. $E_g = 0.67\ eV$ (Ge)
2. $E_g = 1.1\ eV$ (Si)

* Doping:-

(التطعيم) (التنشيط السيليكون)

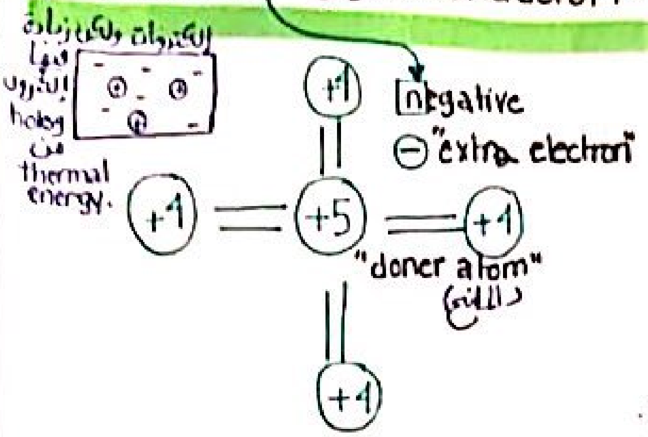
هي عملية إضافة شوائب

* لما حكينا عن الـ diodes حكينا إنه تتكون من p-n junction.

ملاحظة: الهدف من هنا تحويل المادة من شبه موصلة إلى موصلة.

* هي عملية تمنح من خلالها نضيف Free charge carriers يعني يا نضيف Free electrones يا holes في الـ pure semi conductor material لنزيد الـ conductivity.

* N_TYPE Semi_Conductor:- هو عبارة عن PURE Semi-Conductor مضاف عليها ذرات عددها الذري يعطي فالمدار الأخير 5e، مثل الفسفور.



فكل ذرة محاطة بـ 4e فمشو لتصير المحاطة ذرة إلها 5e فالمدار الأخير فـ 1e راح تشارك ويزيد إلكترون يسمى (Free electron) ويكون (extraelectron) فيسمى إلى إلها (5e) تسمى (doner-electron atom)، ممكن أكثر من doner يعني عملية الـ doping متحكم فيها.

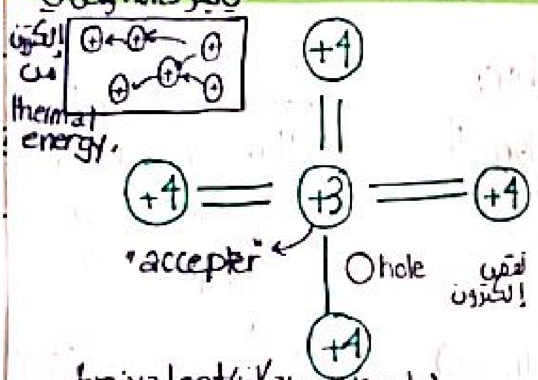
* مازال الـ material متعادل.

Benta_ vialent impurities. (شائبة)

* منفنا إلكترونات تسمى ← majority current carriers.

وغيرهيك إذا درجة الحرارة مش صفر فيوجد holes ← minority carriers ولكن عددهم قليل والإلكترونات كثيرة.

* P_TYPE Semi_Conductor:- Ga/B(boron) having 3 electrones.
٣ روابط تشاركية والـ الرابعة hole.

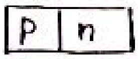


trivalent (مادة ثلاثية التكافؤ)

* ممكن يصير لحرارة معينة ويكون عنا holes majority carriers
Free electrones مكانه. ↓ minority carriers.

Notes

* Pn-junction:

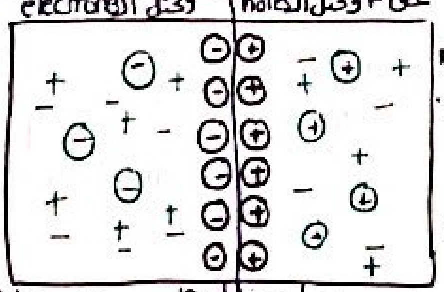


1. P-TYPE & N-TYPE لما تنضم لبعض صار Pn-junction

2. في الـ Resistor فيوجد فقط negative or positive charges ما في holes فيها زي holes في semi & electrone. con.

عملية الانتقال للإلكترونات من الـ n لـ P راح تشكل (+ آيونات) لـ n وتشكل (- آيونات) عند P وتستمر لفترة معينة لحد إذا بده ينتقل الـ e من الـ n لـ P بده طاقة كافية ليتخطى الحاجز وبالنتيجة ما راح يكون فيه وتوصل للـ steady-states ما فيه تيار صار فرق جهد.

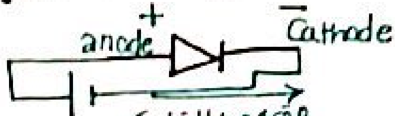
بتحمل الـ e راح تشغل الـ holes وتخلي الـ P على
أو بعض الـ holes تشغل وتخلي الـ electrones



(حاجز) Deplation region * يعني تفريغ من فيها ما في لا إلكترون ولا holes بالتالي فش حركة ولكن هناك فرق جهد ويعني بطارية كأنه فيسمى Barier Potential وهميه
Si = 0.7
Ge = 0.3

تعتمد على المادة المصنوع منها الـ Transistor / يعني إذا بدي حركة واتجاه التيار فيه :
hole current P→n من الشمال للمين
electrone current n→P المين للشمال

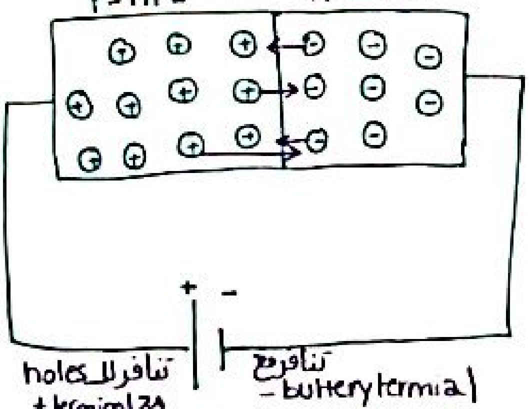
ملاحظة: زي ما اعتمدنا Positive charges راح نعتمد بالelectronic راح نعتمد Positive charges للاتجاه الDiode



مصدر بالبطارية
لازم أحط الجهد على ال cathode أعلى من anode
ولازم يصير فرق جهد لمروره مثلاً نشبكه مع بطارية ممكن
لقدرال holes انتقل بعد ما حصلت على energy من P→n.
وتسمى البطارية الخارجية (Biase).

YOUTUBE: في عندنا ما يسمى ب ← depletion region

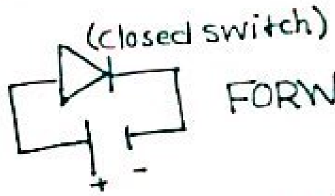
وهنا الحاجز الذي يمنع مرور التيار إلا في حالات غير ذلك، وعوامل خارجية وممكن نخطيها مع مصدر جهد خارجي.



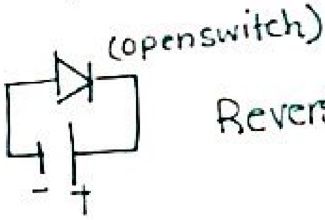
* عن خلال هذه الصلة تمكن الشحنات من المرور عبر ال Junction وتولد التيار الكهربائي.

Si → 0.7
Ge → 0.3
* بعدهم يصير موصل جيد للتيار الكهربائي

PN-JUNCTION DIODE:



FORWARD Biased.



Reverse Biased.

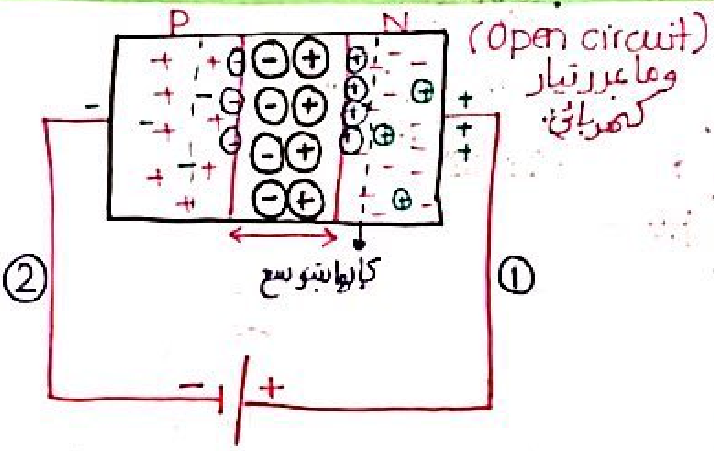
L2: Electronics: (1-6-2020)

PART(1):-

* مراجعة لـ L1 :- majority carriers (electrons) ← → majority carriers (holes)
مكنيا الـ Semi conductor لهم نوعين N & P TYPES .

فلاحظوا أثناء التصنيع مع تصنيع P-N تتكون في منطقة التقاطع إنتقال الإلكترونات من N ← P أو الـ holes من الـ P ← N ، ولو أخذنا الـ N region هو متعادل كشحنة ولا يوجد فيه "ions" ولكن عند ربطهم ببعض يصير ربط بينهم وما نسميه الـ defusion ، وعند إنتقال الإلكترون من N ← P فهي تفقد إلكترونات وتصير شحنتها سالبة والعكس في P تصبح سالبة لأنها تكتسب ، وفي فترة معينة يصير steady state للـ P-N Junction ، ويصير الـ ions ثابتات في مكانهم.
(كأنه عازل روابط بينهم negative & positive ions.)

* Reverse bias of a PN - JUNCTION:-



بدنا نوصل مصدر جهد خارجي للـ P-N JUNCTION ممكن نخليها حالة مستمرة في عدم عبور التيار وهذا نسميه (biasing) هو مصدر جهد خارجي تضيفه سواء لتمرير التيار وجعله موصل أو لتوقيفه ويجعل موصل.

في كلا الـ P TYPES تحتوي على إلكترونات وفجوات إضافية من الحرارة.

NOTES: (وهاد كل الحكي للـ majority carriers)

A ① ② ستقوم الإلكترونات بالإنجذاب نحو الشحنات الموجبة وتبقى القليل من الـ holes للمنافرة معها وتقترب من الـ ⊕ ions وهذا يؤدي إلى توسيع الـ depletion region وكذلك في منطقة الـ P-TYPE .

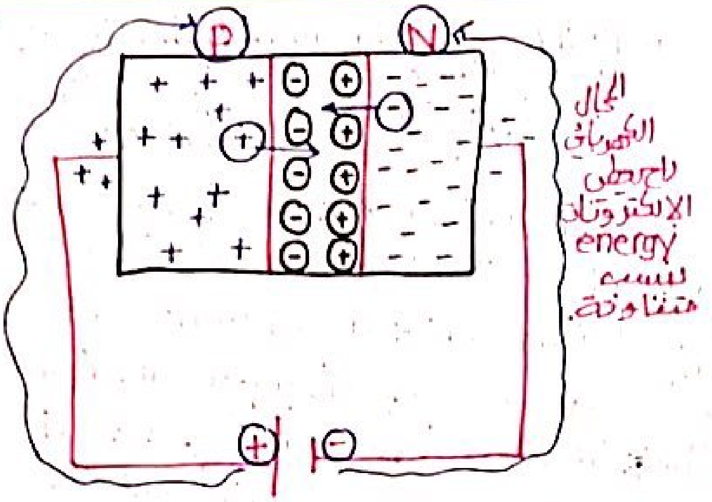
B كل ما زادت منطقة الـ depletion تكون بسبب زيادة الفولتية تحت الـ biase .

C ما في close LOOP لمرور تيار كهربائي بسبب منطقة الـ depletion .

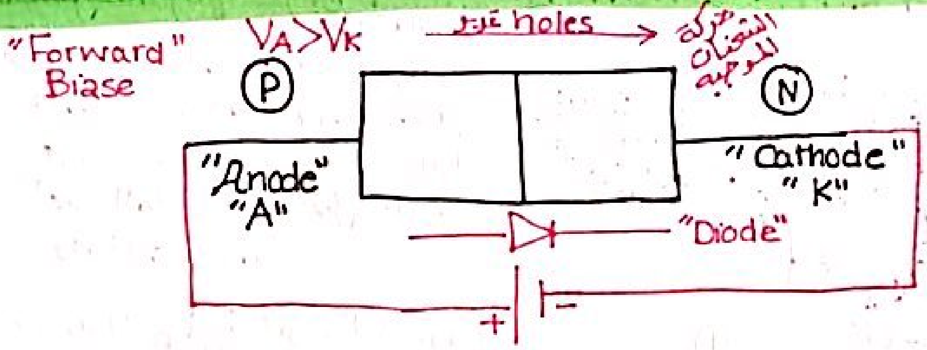
D وممكن وضع جهد أو طي من جهد الـ N region في الـ P region أو تضع القطب الموجب مع N والسالب لـ P وهنا نسميه الـ Reverse biase .

* ولكن تيار الـ minority carriers ممكن شحنة موجبة من الـ N تعبر للـ P أو سالبة من الـ P تعبر للـ N وهو تيار قليل جداً ونهمله حتى لو حصل.

* Forward biase of PN-JUNCTION:-



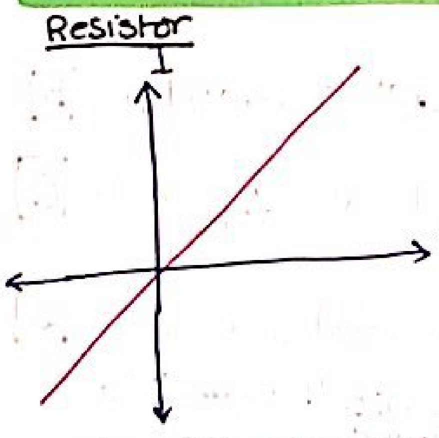
في حركة تشكل close LOOP للتيار التي تستمع لها التغلب على جهد الـ depletion area ، وأما حركة الإلكترونات من اليمين للشمال أو من الشمال لليمين أو الـ holes ، فيكون مرور التيار مع أو عكس عقارب الساعة .



IL Diodes
ما بنبشين .

* Barrier Potential:-

مقدار فرق الجهد المتكون في الـ diode
أثناء تصنيعه مقداره تقريبًا ≈ 0.7 من Si
≈ 0.3 من Ge
ودرجة الحرارة بتأثر عليه



علاقة التيار مع فرق الجهد ثابت الـ Resistor .
ممكن تكون موجبة أو سالبة .

Diodes

ولكن بالنسبة للـ Diodes في إله ثلاثة Operation regions : العلاقة غير خطية وهذا صعوبة للـ analyze

1. إذا الفولتيج على A > K عبر تيار من الشمال لليمين وسيمى FORWARD BIASE .
2. إذا عكسنا الفولتية ما عبر تيار أو صغير جدًا وأسمه Reverse Biase .
3. وإذا كان في قيمة معينة للفولتية السالبة على الـ diode يخرب الـ diode تسمى Reverse breakdown .

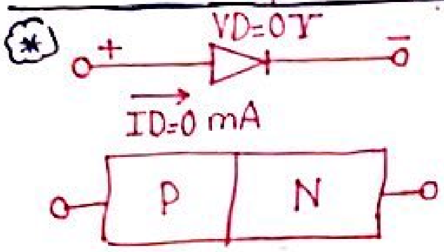
PART(2):-

* 3 Operating Conditions For Diodes:

1. NO Bias Condition:-

1. ما في applied external voltage
2. ما في أي current عبر Diode.
3. في Depletion region صغيرة موجودة

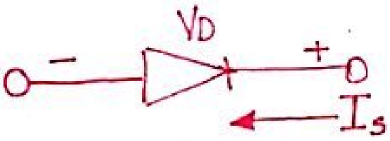
(*) • VD = 0 V.
• ID = 0 A.
• Small depletion region.

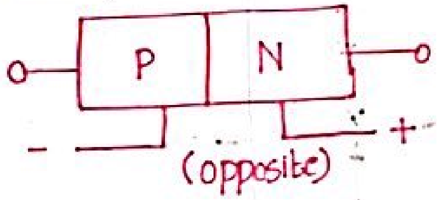
(*) 

(no bias).

2. Reverse Bias Condition:-

- external voltage with ~~positive~~ opposite polarity for P-N junction.





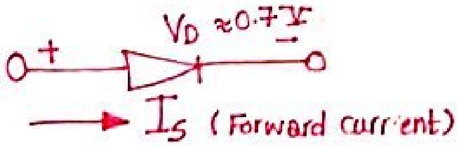
- هنا لا يوجد تيار كبير ولكن يوجد تيار من اليمين للشمال وهو صغير جدًا

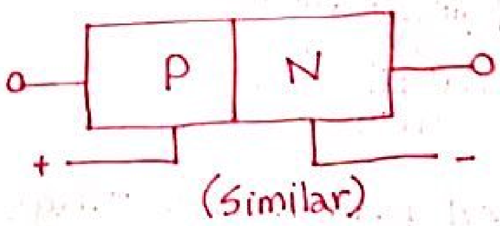
- ويسبب في زيادة بال Depletion region.

- والفولتيج الموجود على الـdiode هي نفسها VD وهي V biase ولكن بالسالب P مع (-) و n مع (+).

3. Forward Bias Condition:-

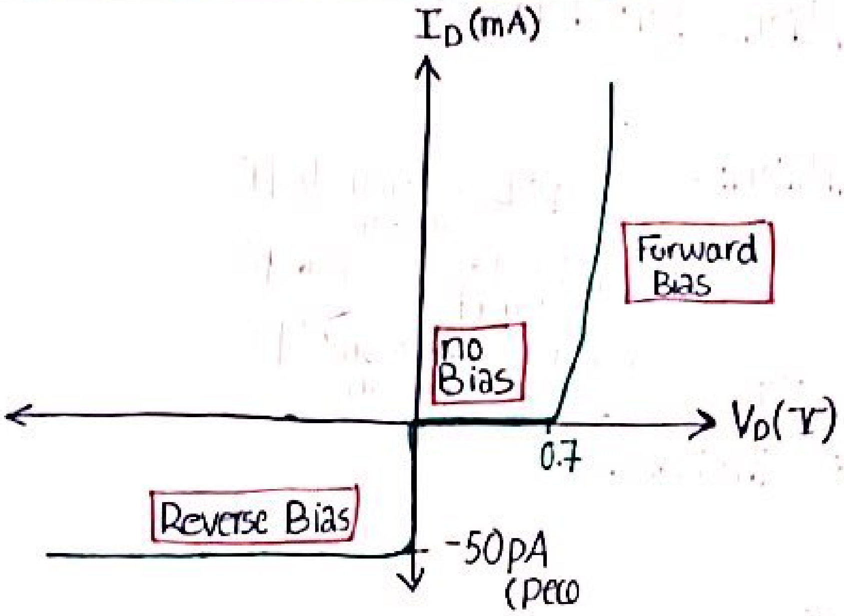
- external voltage which is in P-type higher than N-type.



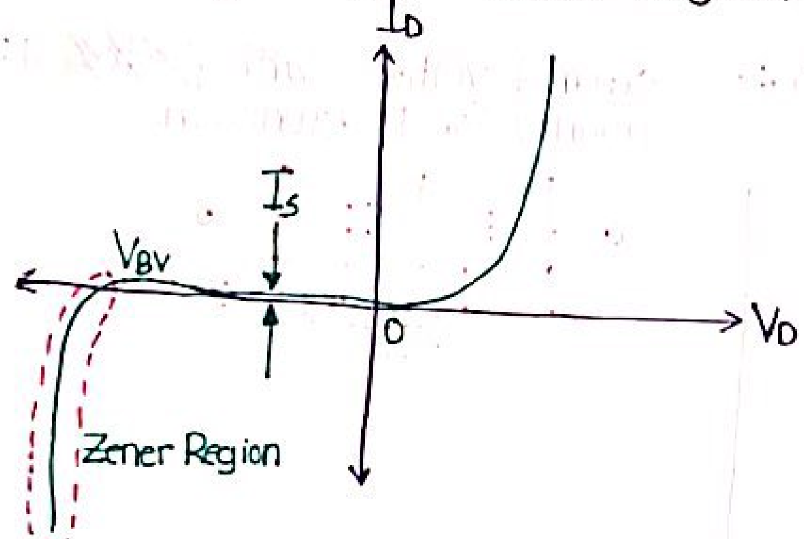


- يؤدي إلى تقليل الـdepletion وبالتالي تكون تيار صرف بين الـmajority وتيار الـmanority .3.

* Actual Diode Characteristics:-



* Zener Region (Breakdown Region):-



Diodes & semi-conductors
إذا استخدمناها بشكل خاطئ
سواء للـ V وللـ I بتنحرق
وحط فولتية موجبة أو سالبة أكبر
من المسموح فهون بزيد تيار الـ reverse
بزيد بشكل فلكي وهو سببه في
minority carriers من electrons & holes
تزيد سرعتهم بشكل كبير ويغيرو
اتجاه الـ majority carriers.

* we know peak Reverse voltage by datasheet.

* Temperature Effects:-

1- زيادة الحرارة تزيد عدد الـ (minority carriers)

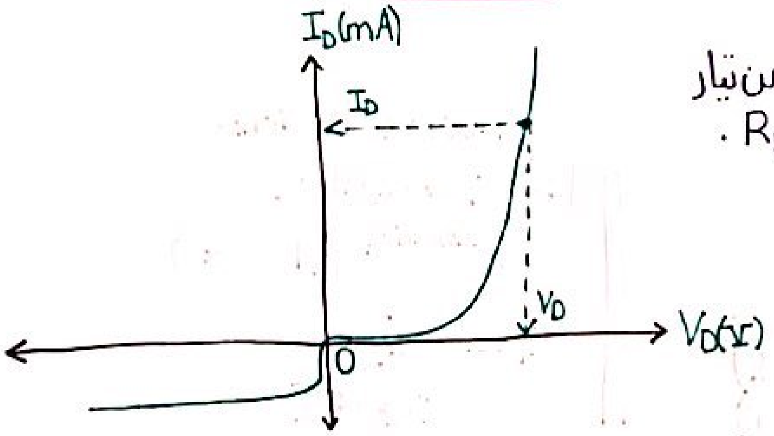
وبالتالي تزيد الـ Reverse conduction (زيادة الـ reverse current) بالإضافة لتكبير الـ Forward conduction (تقليل الـ Forward voltage).

2- ولكن زيادة الحرارة على الـ Diode يؤدي لعمل Failure دائم لهذه الـ device.

* Resistance Levels:-

1. DC (Static) resistance
2. AC (Dynamic) resistance.
3. Average AC resistance.

* DC (Static) Resistance:-



- لكل قيمة لـ V_D إلها قيمة بتمر ها من تيار كهربائي، ولو قسمناها $R_D = \frac{V_D}{I_D}$.

* AC (Dynamic) Resistance:-

1. Forward Bias → $r_d = \frac{\Delta V_d}{\Delta I_d} = \frac{26\,mV}{I_D}$ (DC current) (قيمة صغيرة كثير)

2. Reverse Bias → ∞

* Average AC resistance:

- المقاومة تغيرت بين نقطتين والتيار كذلك $r_{av} = \frac{\Delta V_d}{\Delta I_d}$

(الرسمة + تلخيص الثلاث حالات بالسلايدات).

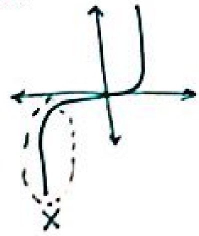
* Diode Equation:

non-linear eq. so, diode non-linear device.

$$i_D(t) = I_s \left(e^{\frac{V_D(t)}{\eta V_T}} - 1 \right)$$

- $i_D(t)$: Forward current
- I_s: 10^{-12}, 10^{-14} — constant
- $V_D(t)$ → voltage for forward.
- η → eta (From design of Diode)
  - 1 → Ge
  - 2 → Si (small current)
  - 1 → Si (high current)

Forward / Reverse تتخطى
ماتتخطى ال break down



* V_T → (Thermal VOLTAG)

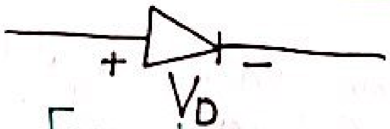
$$= \frac{T}{11600} \text{ ; T in Kelvin.}$$

NOTE: $0°C = 273 K$.

~~0°C = 237 K~~

EXP: room = 37° → 300 K,

$$V_T = \frac{300}{11600} = 25.69 \, mV.$$



1. Forward region:-

V_D → positive

$e^{(positive)} > 1$

$$i_D(t) = I_s \left(e^{\frac{V_D(t)}{\eta V_T}} - \cancel{1} \right)$$

بنقدر نهملو

2. Reverse Region:-

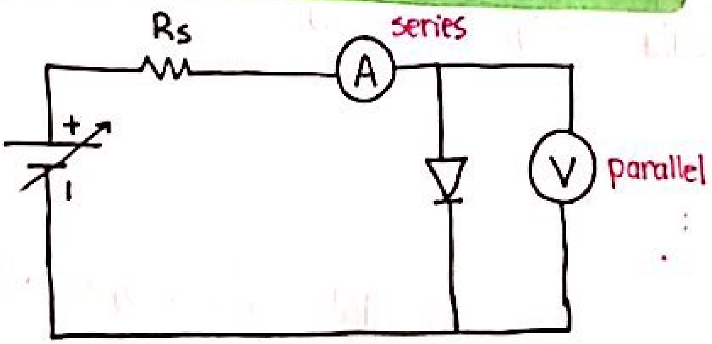
V_D → negative

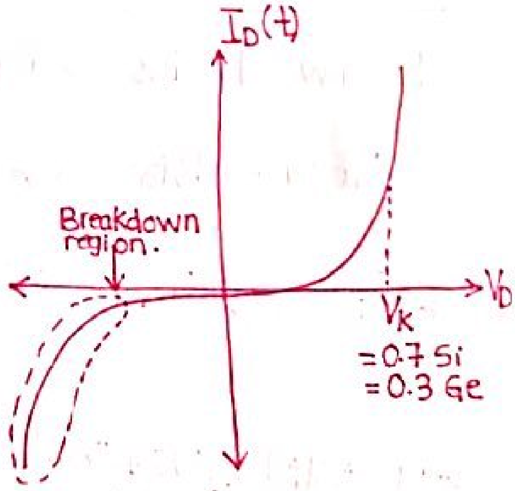
$e^{(negative)} < 1 \approx 0$

$$i_D(t) = -I_s$$

(قيمته صغيرة)

* Diode V-I Characteristic curve:-

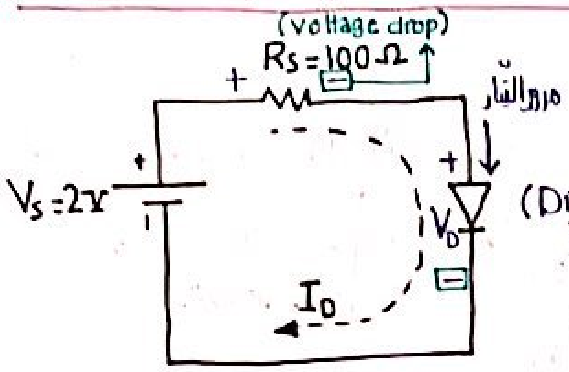




* Approaches to Diode Circuit Analysis:-

1. NON-linear.
2. graphical.
3. equivelant Circuit.

*NON-LINEAR EXAMPLE:- (فقط للعلم بالطريقة)



(Diode is Forward)
$V_A > V_K$

FIND I_D, V_D?

KVL: $V_S = R_S I_D + V_D$ ------ ①

$I_D = I_S \left(e^{\frac{V_D}{\eta V_T}} - 1 \right)$ ---- ② but Since it's Forward biased $I_D = I_S \left(e^{\frac{V_D}{\eta V_T}} \right)$

$$V_D = \eta V_T \ln \frac{I_D}{I_S} \quad \text{-----} \; ②^*$$

$$\therefore V_S = R_S I_D + \eta V_T \ln \frac{I_D}{I_S}$$ (non-linear equ.)

* Back to Find I_D → $I_D = \frac{V_S - V_D}{R_S}$.

$V_D = \eta V_T \ln \frac{I_D}{I_S}$. ⇒ USING *Iterative Analysis.

Let $V_D = 0.7v$, $I_D = \frac{2 - 0.7}{0.1K} = 13$ mA.

$V_D = 0.7882392v$ → *The error is large. (إذا الإيرور مقبول بوقف ولكن إذا كبر نعيد مرة أخرى على هذه القيمة.)

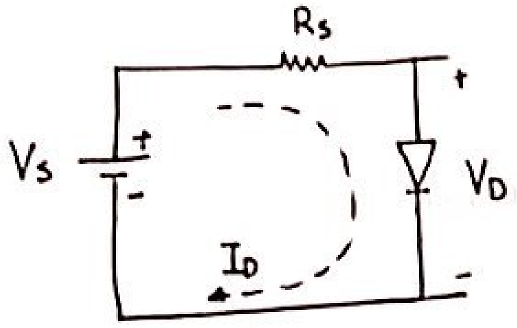
Let $V_D = 0.7882392v$, $I_D = 12.117608$ mA.

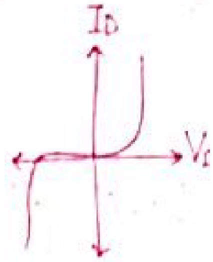
$V_D = 0.7862529v$ → The error *is small. (إذا الإيرور مقبول وبحكي هذه القيمة)

⋮ the error getting smaller.

* Graphical Techniques:-

(Requires the VI exact plot) – بإمكاني استنى لما الرسمة تكون عندي.





KVL (I (Forward) اتجاهه الزلمي :- $V_s = R_s I_D + V_D$ (مهمين لأن العلاقة بينهم)

$$I_D = \frac{V_s - V_D}{R_s} = \boxed{\frac{-1}{R_s} V_D + \frac{V_s}{R_s}} \quad \dots\dots (1)$$

"linear eqs."

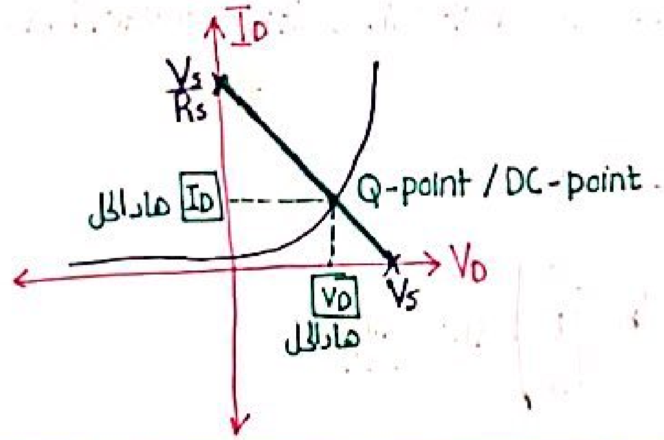
* V_s & R_s are constants
* V_D is Variable.

So, eqs.(1) $\rightarrow I_D = \frac{-1}{R_s} V_D + \frac{V_s}{R_s}$

Draw eqs.1:-

$V_D = 0 \rightarrow I_D = \frac{V_s}{R_s}$

$I_D = 0 \rightarrow V_D = V_s$



* Diode Modles:

1. Ideal Diode Model.
2. Simplified / piecewise / Knee Model.
3. Complete diode Model.

* نستبدل الـ Diode إما ب
  1. open circuit
  2. short circuit
  3. Voltage source
  4. or voltage source + Resistance.

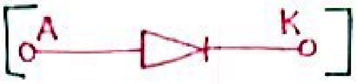
L3: Diode Modles (PART .1.): (6-6-2020):-

← أول خطوة قبل هذا نتعرف الـdiode ← · Forward / · Reverse

Diode: it maybe define as Forward / Reverse Bias device.

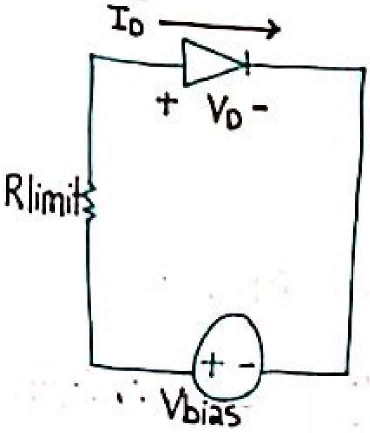
* ideal diode Model:-

1. Forward: $V_A > V_K$ →

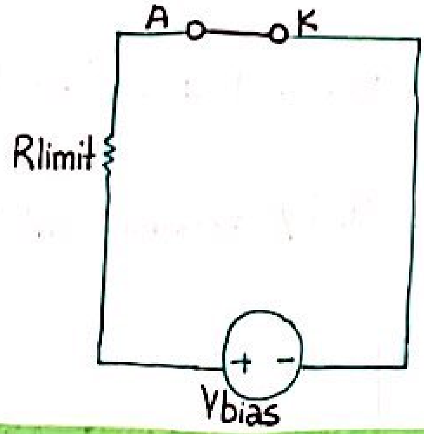


we can replace it by a short circuit.

EXP: FIND V_d, I_d?



→



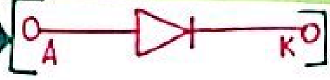
* AFTER Analysis:

$V_D = 0$

$I_D = \frac{V_{bias}}{R_{limit}}$

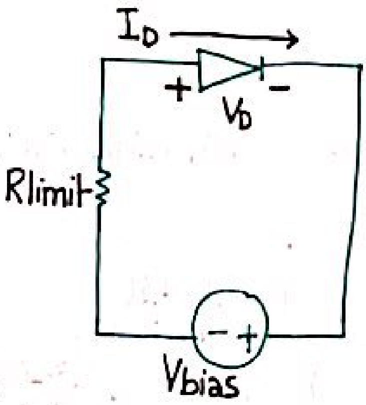
* ideal diode Model:-

2. Reverse: $V_K > V_A$ →

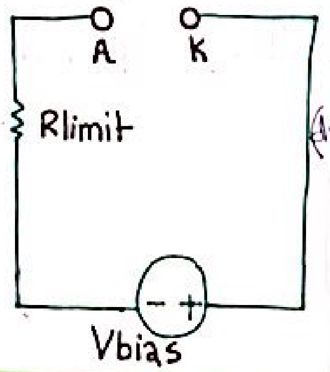


we can replace it by an open circuit.

EXP: FIND V_d, I_d?



→



* AFTER Analysis:

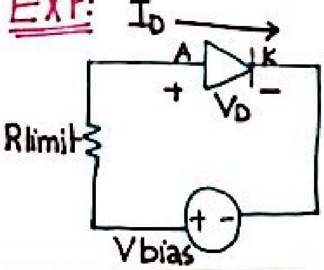
([illegible]) $V_D = -V_{bias}$.

$I_D = 0$.

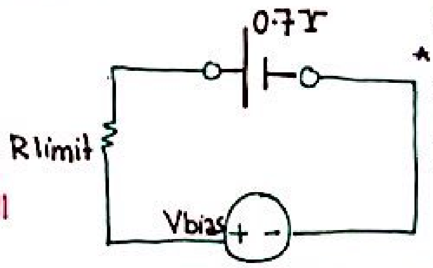
* Simplified / Knee Model:-

1. Forward: إذا كان الـdiode Forward نضع بداله بطارية تقريباً قيمتها 0.7V للـ(Si).

EXP:



we want to replace diode by a battery
we have to be carefull for the Polarity.!.



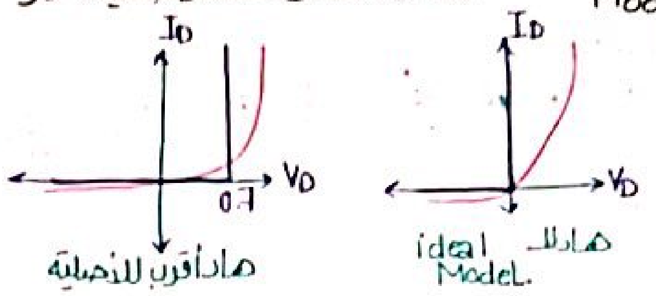
* After Analysis:

$V_D = 0.7$

$I_D = \frac{V_{bias} - 0.7}{R_{limit}}$

2. Reverse: we replace diode by Open circuit as (ideal Model).

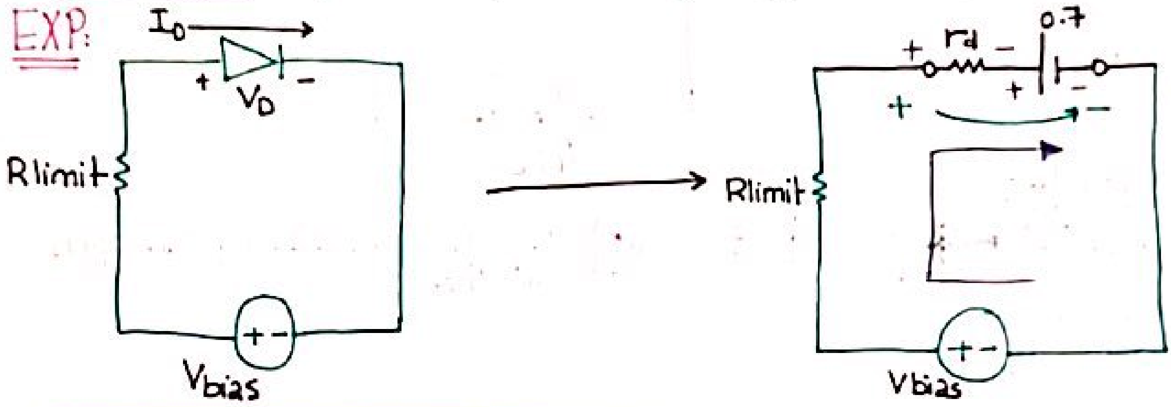
ملاحظة: Simplified Model أحسن وقريب من الرسمة الأصلية أكثر



* Complete diode model: (ماراح ندخل عليها)

1. Forward: replace it by a battery with 0.7 V + Dynamic resistance.

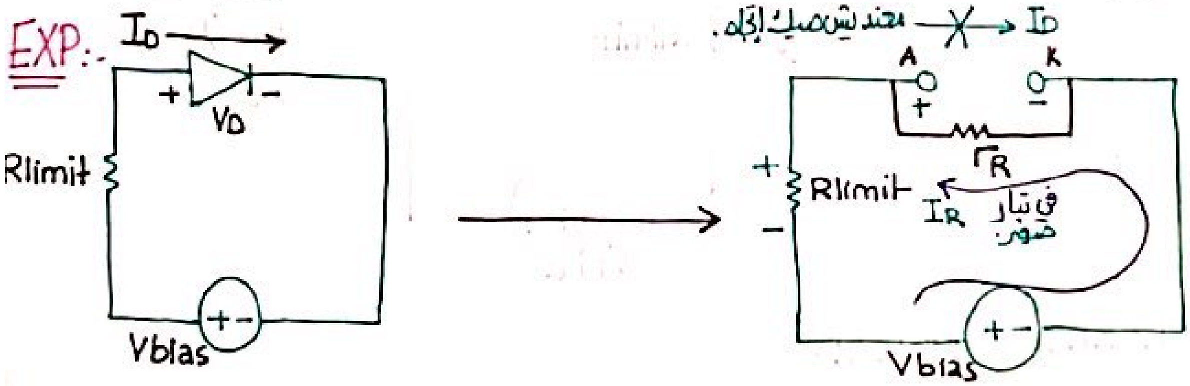
EXP:



* AFTER Analysis:
* $V_D = 0.7 + r_d \cdot I_d$
* $I_D = \dfrac{(V_{bias} - 0.7)}{(R_{limit} + r_d)}$

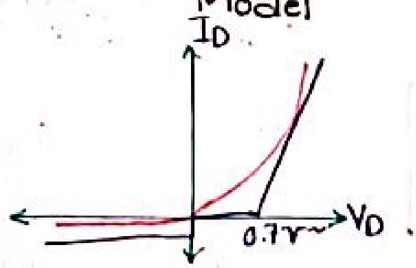
2. Reverse: replace it by Open circuit + reverse resistance with high valu

EXP:-



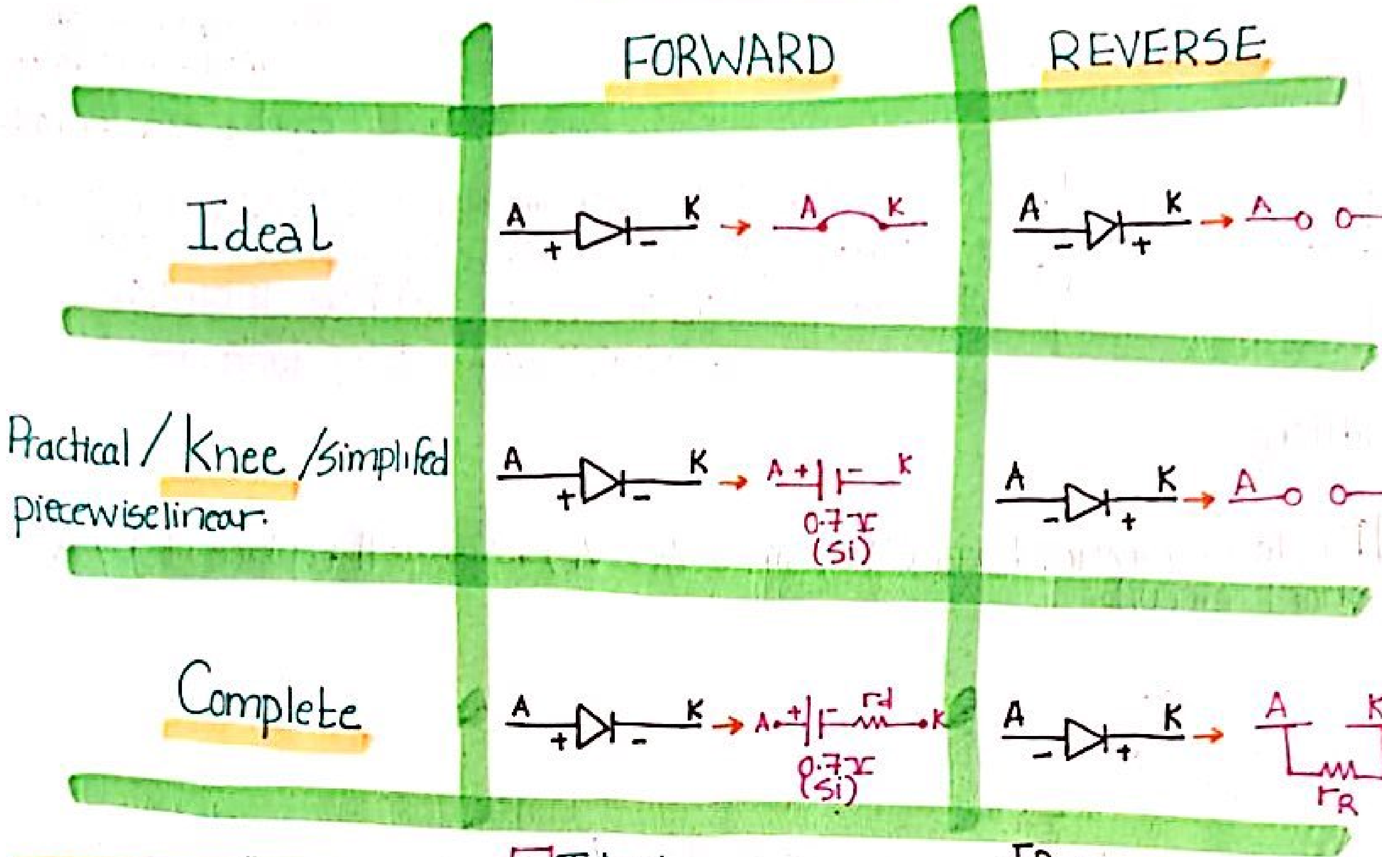
* AFTER Analysis:-
* $V_D = -V_{bias}$ (تقريبية)
* $I_d = -I_R$

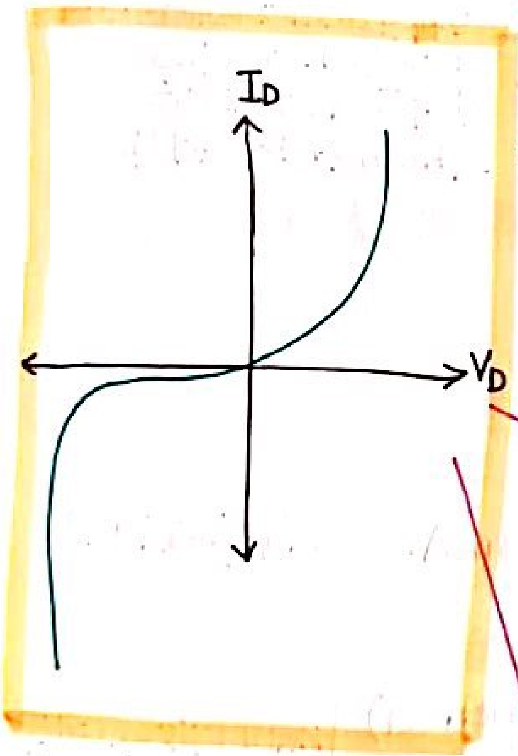
ملاحظة: الـ Complete Model اقترب أكثر من الـ diode.



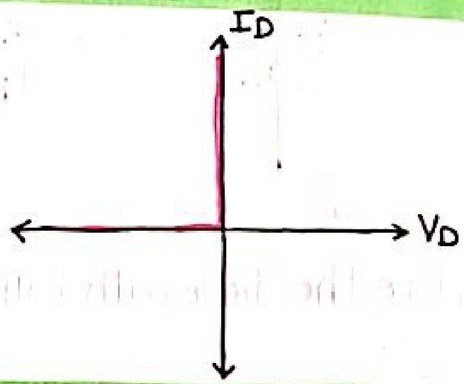
*تلخيص كامل للـ 3 أنواع :-

Diode Model

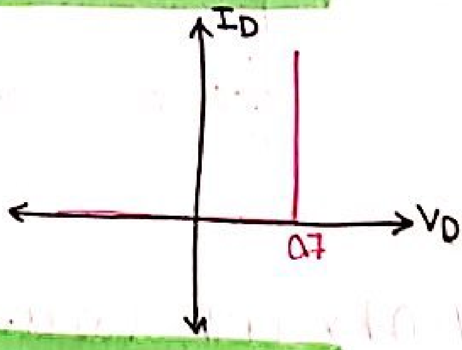




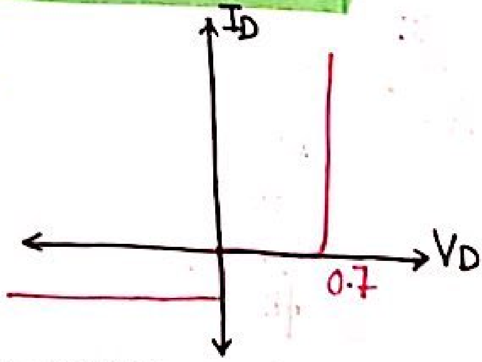
1. Ideal:-



2. Knee:-



3. Complete:-

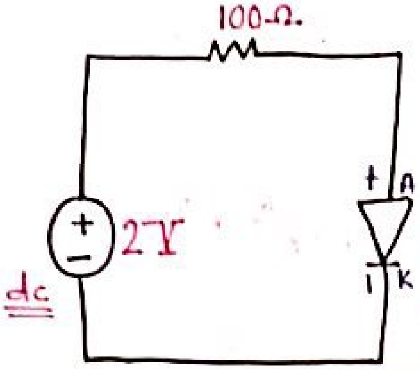


* EXAMPLE:- FIND Q-Point (I_{DQ} & V_{DQ}) (نقطة الحل)

a. Use diode ideal Model.

b. Use practical diode Model.

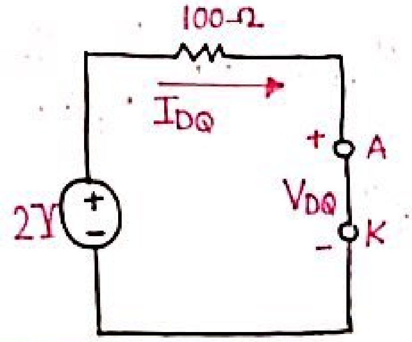
c. Use exact model.



ملاحظة: لو بدي اختار أنا أي طريقة استخدم؟ إذا كان الـ bias أكبر بكثير = 7V الفرع الأول 70mA والثاني 63mA وهنا الإيرور مش كثير 10% وبالتالي إذا الـ bias voltage أكبر بـ 10 أضعاف من 0.7V للـ diode ساعتها الـ ideal أفضل إذا لا نستخدم الـ practical.

Solution:

a. Diode is Forward Bias (ON, since $V_A > V_K$), so we'll replace it by a short circuit.

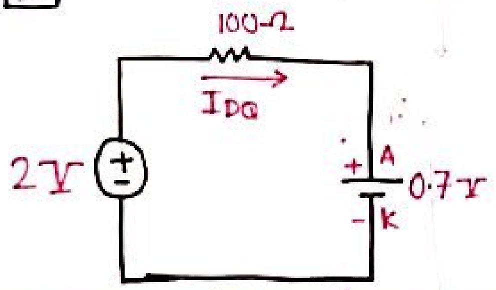


→ $V_{DQ} = 0V = V_{AK}$

$I_{DQ} = \frac{2}{100} = 20mA.$

(في هذه الحالة المصدر الجهدي هو عبارة عن dc وليس ac ولكن إذا كان ac لازم أحكي بالـ Reverse + Forward).

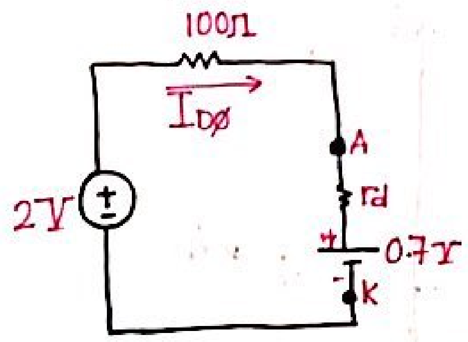
b. Replace the diode with buttery = 0.7V.



→ $V_{DQ} = 0.7V$

$I_{DQ} = \frac{2-0.7}{100} = 13mA.$ (الحل أدق بكثير).

C. buttery = 0.7V + rd. (as exact → as iterative method)



→ $V_{DQ} = 0.786V.$

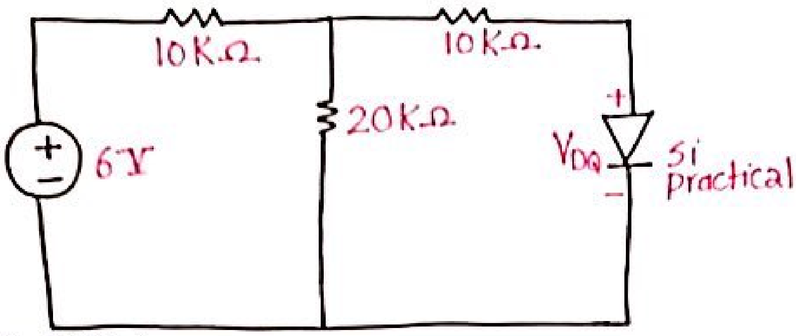
$I_{DQ} = 12.14mA$

لنأخذ دين أفضل الـ ideal أو الـ practical بالنسبة للـ exact method ←

$\frac{20}{12.14} = 65\%$ error

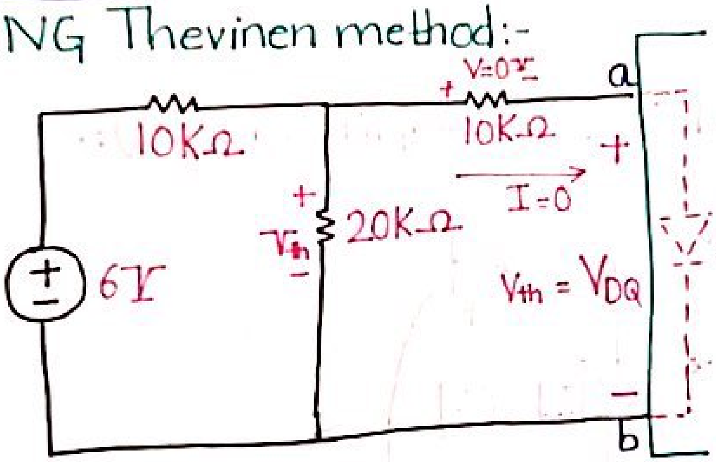
$\frac{13}{12.14} = 7\%$ error أفضل

★ EXAMPLE: FIND Q-Point (I_{DQ} & V_{DQ}):-

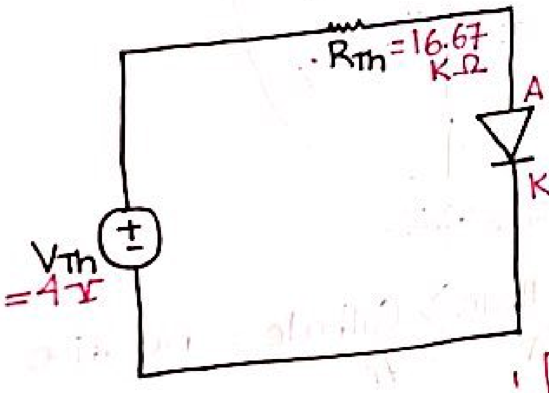


SOlUTION:

USING Thevinen method:-



هي طريقة وين مابدي أوجد الـvoltage بشيل الـdevice وبعدها بوخذ أسهل مسار.

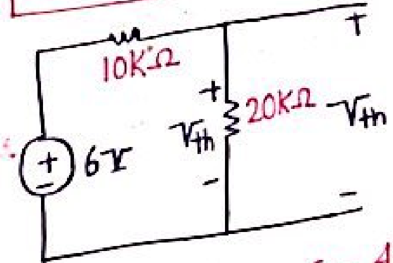


1. R_{Th}

(Voltage source be as a short Circuit)

$R_{th} = (10//20) + 10 = 16.67\ K\Omega.$

2. $V_{Th} = V_{DQ}$

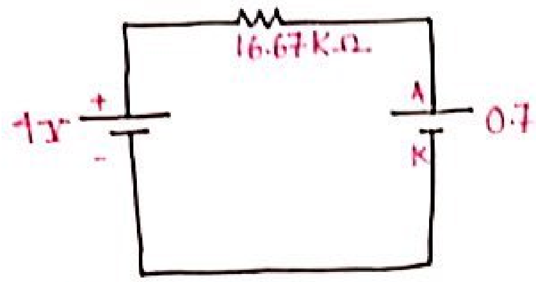


$V_{th} = \frac{20K}{20K+10K} \cdot 6 = 4V$

From Slides

Scanned with CamScanner

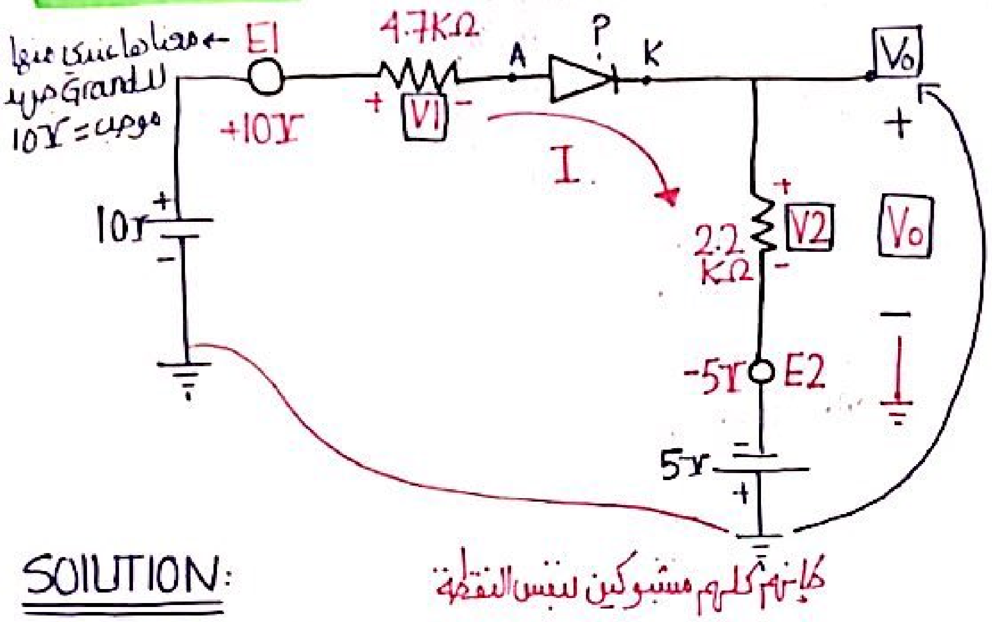
USING "Practical Method":-



$V_{DQ} = 0.7V$.

$I_{DQ} = \frac{4-0.7}{16.67}$.

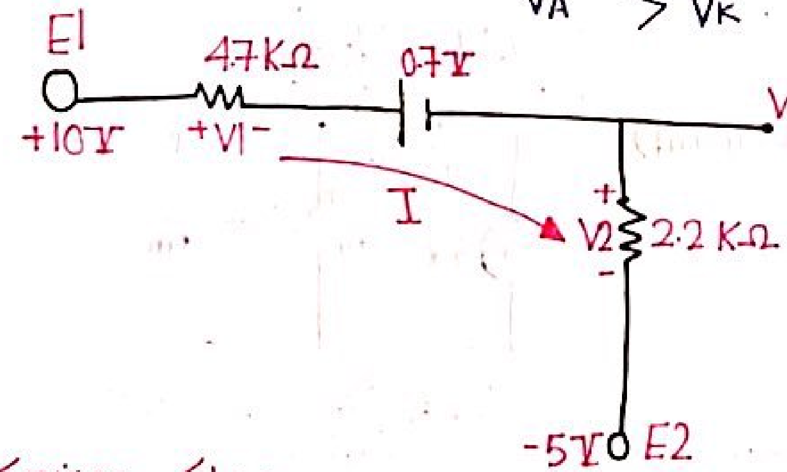
EXAMPLE:- FIND I, V1, V and Vo (USE Simplified Model):-



SOLUTION:

Anode For diode has a positive voltage > Cathode is negative. (Forward diode)

$V_A > V_K$.



KVL: Σ rises = Σ drop

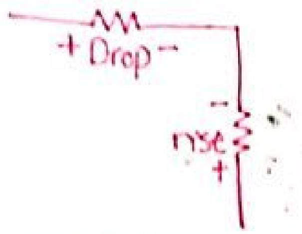
$10 + 5 = I*4.7 + I*2.2 + 0.7$

(KVL):- $-10 + 1.7I + 0.7 + 2.2I - 5 = 0$

$$(-15 + 0.7) + (1.7 + 2.2)I = 0$$

$$I = 2.07\,mA$$

* KVL ⇒ Σ rises = Σ drops

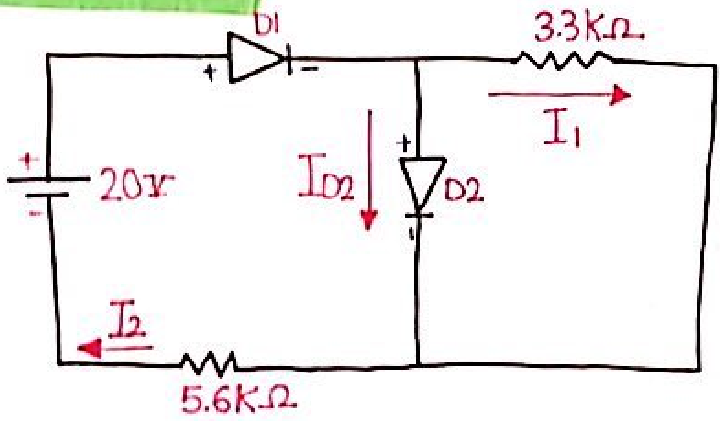


$V1 = I.R = 9.73\,V$

$V2 = I R = 4.55\,V$

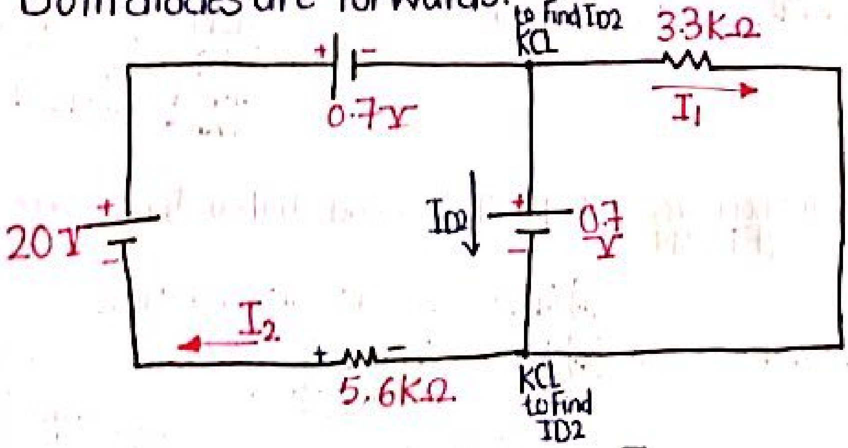
$V_o = V_2 - 5 = 0.45\,V$

* EXAMPLE:- FIND I1, I2, I_{D2} (USE Practical Model):-



SOLUTION:

Both diodes are Forwards.



* I_1 Parallel voltage Source

$$I_1 = \frac{0.7\ V}{3.3K\Omega} = 0.212\,mA.$$

* KVL TO FIND I2:-

$$-20 + 0.7 + 0.7 - 5.6 I_2 = 0$$

$$I_2 = 3.32\,mA.$$

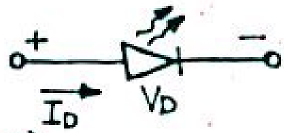
* $I_{D2} = I_2 - I_1 = 3.32 - 0.212\,mA$

* Diode Specification sheets:-

1. معلومة عن V_D (Forward voltage)
2. أقصى تيار مسموح فيه.
3. Reverse break voltage (فولت سالب بجزئ معينه).
4. Maximum Power dissipation at Specified Temperature.

NOTE: Other Kinds For Diodes:

1. Zener Diode in (L6).
2. Light emitting diode. (LED) → Forward Bias يشع ضوء عندما يكون ولها ألوان عدة. ↓ (2,3 V) ليضوي.

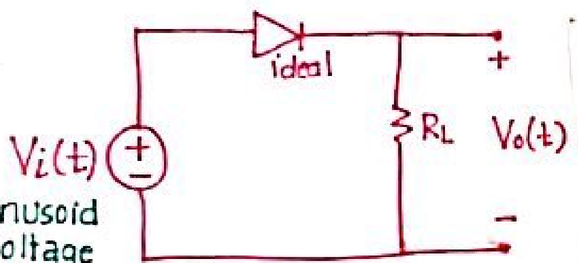


PART(2):-

- مطلوب الـ diode نحل Function معين أو كيف نحله Analysis.

* Diode large- Signal application:-

1. Diode Clipper Circuit.



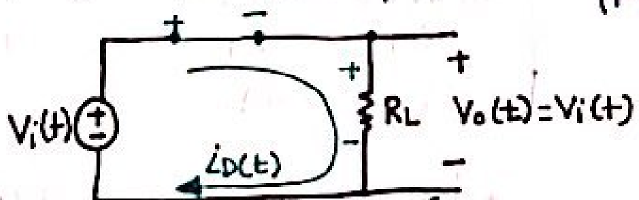
في هذه الحالة نعتبر كأنه مفتاح الـ (diode)

close → ON (short circuit)/(Forward Bias) → للازم تكون V_i موجبة

open → OFF (~~close~~ open circuit) / (Revers Bias) → للازم تكون V_i سالبة

ملاحظة: يمكن وجود قطع أخرى في الدارة تخليني ما أعرف شو للازم تكون V_i ليكون الـ diode ⇒ .FB .RB

- فحص إلي راح نعمله راح نفترض حل الـ diode (short circuit) (FB/ON) ونطلع جميع قيم V_i الممكنة بعدما نحل KVL.



→ 1. $i_D > 0$ (because it's Forward)

2. $i_D(t) = \frac{V_i(t)}{R_L} > 0$ (positive) نشترط

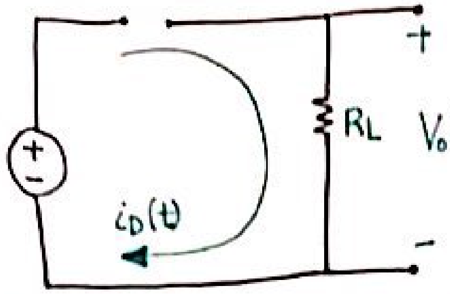
$\therefore V_i(t) > 0$

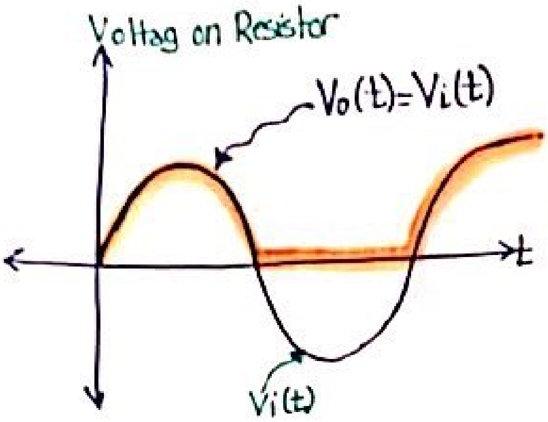
* اتجاه التيار ملزم للـ ON / FB *

ملاحظة: ممكن R_{th} تكون سالبة لما يكون source dependent.

- لهالحالة نفترض كأن مرة حل الـ diode ← (open circuit) / OFF.

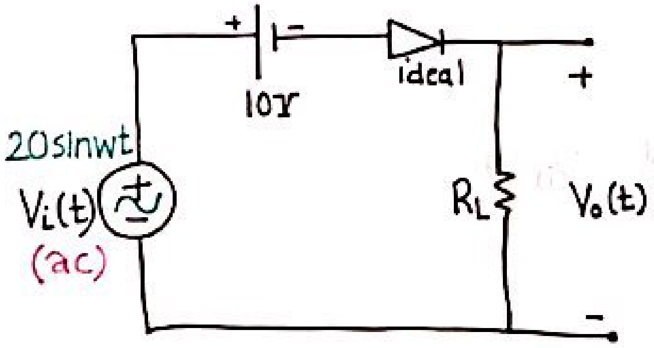
- When $V_i(t) < 0$, the diode is off and $V_o(t) = 0$.

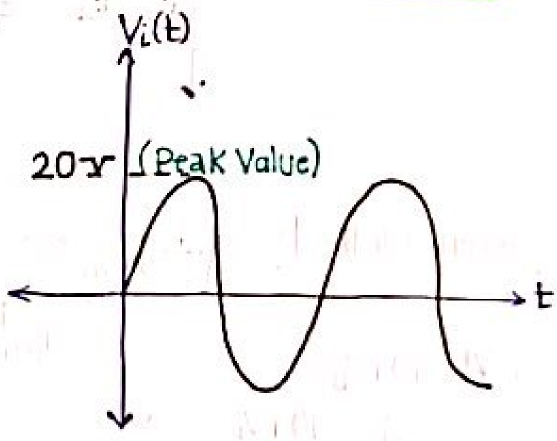




"limitter Circuit / Clipper Circuit"
"Rectifier (AC to DC convertor)"

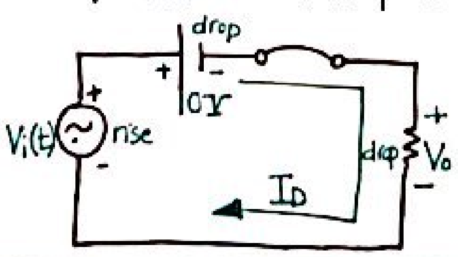
* EXAMPLE:





1. Assume diode is ON / FB:-
USING Ideal Model: (replace it by short circuit):-

ملاحظة/ لحل إشكالية تحديد RB/FB نفترض ونعوض نستطلع القيم لـ V_i التي تجعله بأحد الأنواع.



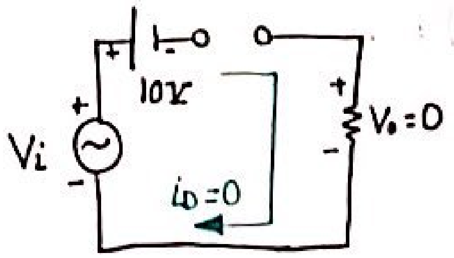
→ KVL:

$V_i = 10 + V_o (i_D \cdot R)$

$i_D = \frac{V_i - 10}{R} > 0 \rightarrow V_i - 10 > 0 \rightarrow \boxed{V_o = V_i - 10}$

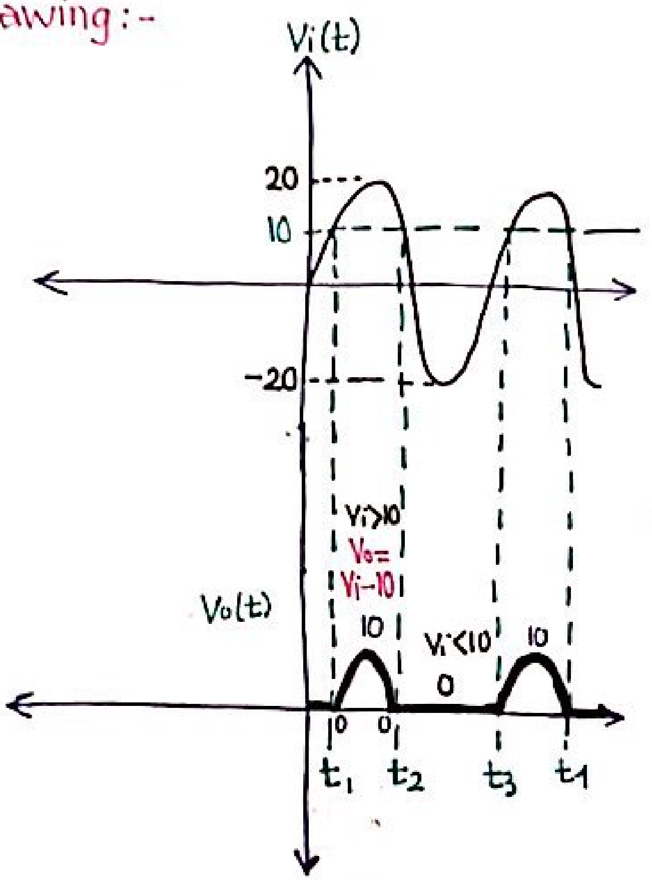
$\boxed{V_i > 10}$ Diode is ON.

2. $V_i < 10$, Diode is (OFF) and (Open Circuit):-



$V_o = 0\,v$

Drawing:-



Second Method: V_D + V_D - drop

لازم انكزانة سالب في حالة الـ open إذا بدي أطلش فيها

$V_D \leq 0$

KVL: $10 + V_D = V_i$

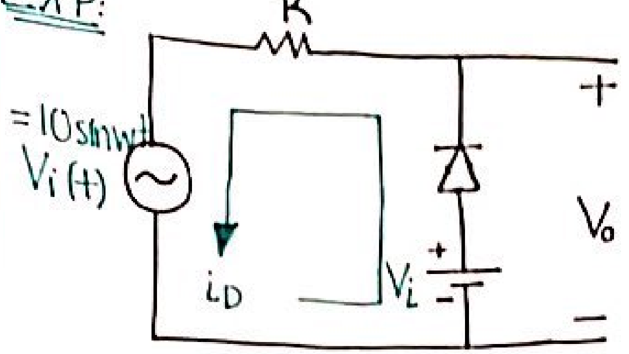
$V_D = -10 + V_i$

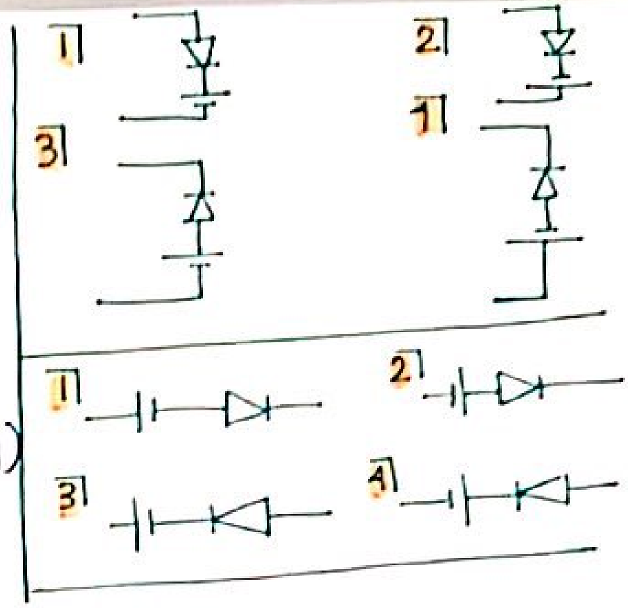
$V_i < 10$ Diode OFF.

$V_i > 10$ Diode ON.

In Slides.

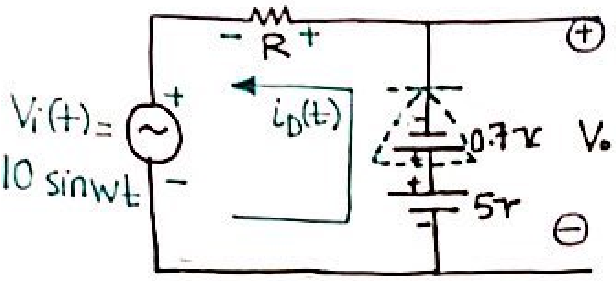
EXP:





SOLUTION: (USING Simplified diode Model)

1) Assume diode is ON/FB.



KVL: $5 = 0.7 + R.i_D + V_i(t)$

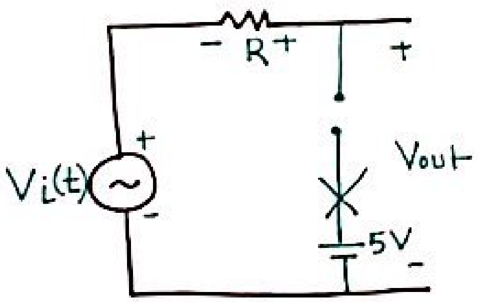
$R.i_D = 4.3 - V_i(t)$

$i_D = \frac{4.3 - V_i}{R} > 0 \rightarrow 4.3 - V_i(t) > 0 \rightarrow V_o = 5 - 0.7 = 4.3v$

$V_i(t) < 4.3v$ (FB)

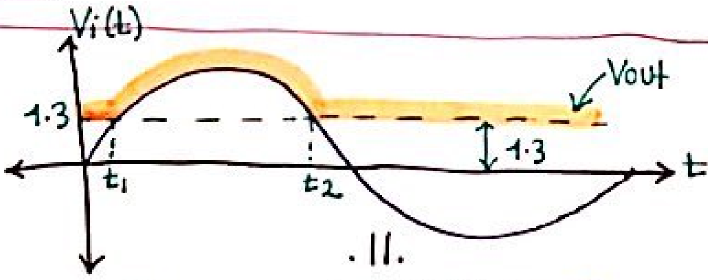
2) Diode is open:- $V_i(t) > 4.3v$

$V_{out} = ?$



$\boxed{V_{out} = V_i}$

Drawing



.ll.

NoTes:-

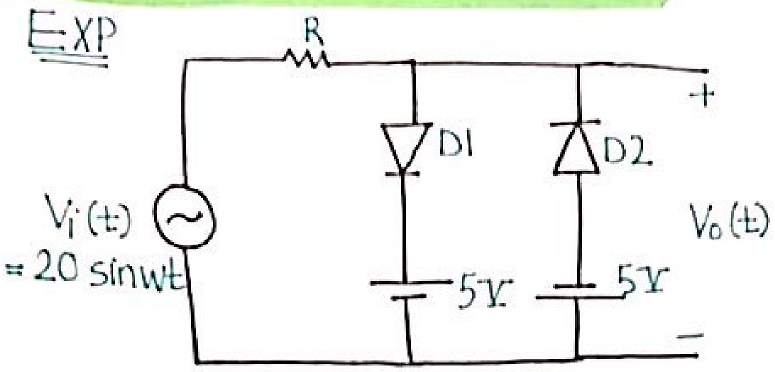
1) $V_i(t) < 4.3$ ↓ $V_o = 4.3$

2) $V_i(t) > 4.3$ ↓ $V_o = V_i$

L4: PART(1):-(8-6-2020)

* Circuit Containing Two Diodes:-

EXP



* ملاحظة:

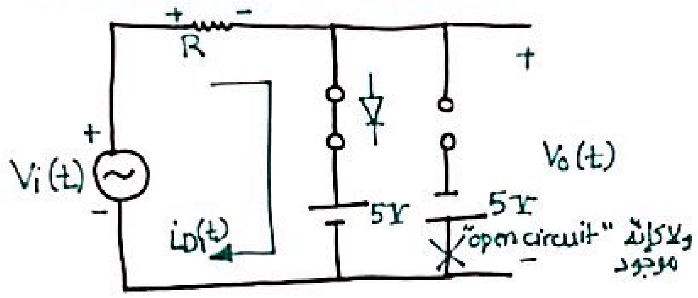
- عند 4 إحتمالات من المصدر sinusoid :-

1. D_1, D_2 ON
2. D_1, D_2 OFF
3. D1 ON, D_2 OFF
4. D_1 OFF, D2 ON

دائماً نبدأ بواحدة منهم

Calculate and ~~switch~~ sketch $V_o(t)$ using ideal diode model:-

1.) Assume D1 ON, D2 OFF:-

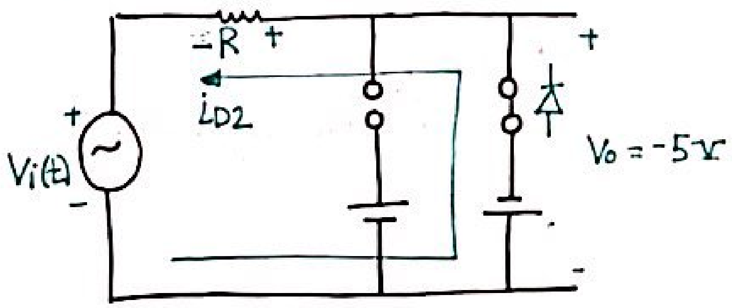


KVL: $V_i = i_{D1} \cdot R + 5$

$i_{D1} = \frac{V_i - 5}{R} > 0 \longrightarrow V_i - 5 > 0 \longrightarrow V_o(t) = 5V$

$V_i > 5$

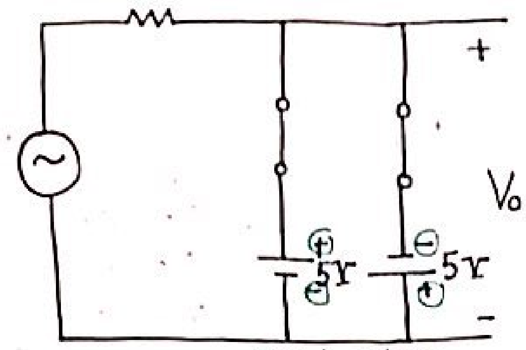
2) Assume D1 OFF, D2 ON:-



KVL : $V_i + i_{D2} \cdot R + 5 = 0$

$i_{D2} = \frac{-(V_i + 5)}{R} > 0 \longrightarrow -V_i - 5 > 0 \rightarrow V_i < -5$

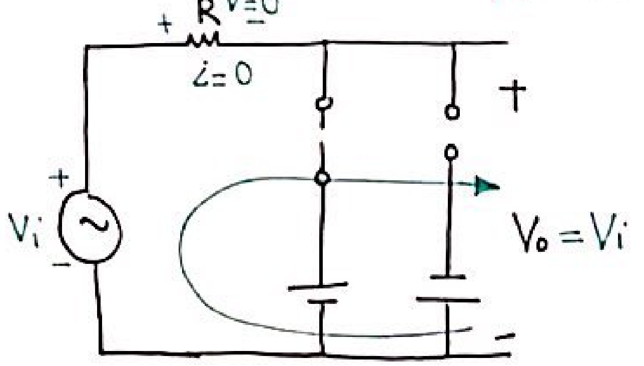
3) Assume D1 ON, D2 ON:-



"not valid"

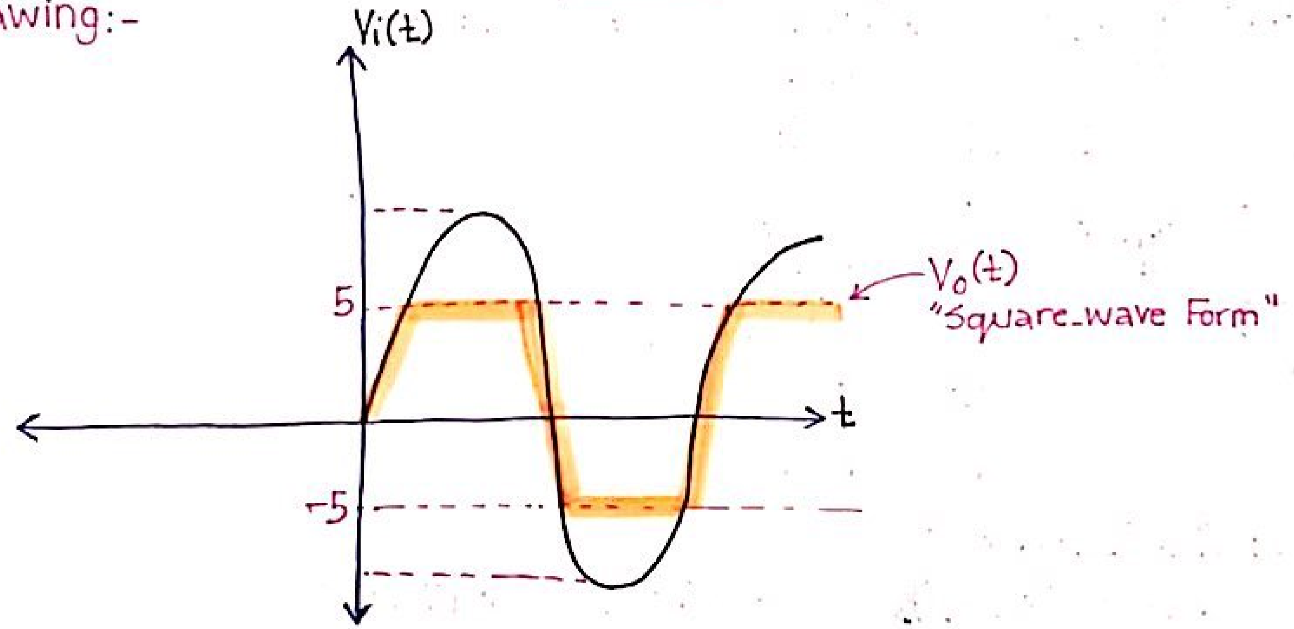
لكونو نفس القيمة وتختلفو بال Polarity

4) Assume D1 OFF, D2 OFF:-



$-5 < V_i < 5$ "الفترة المتبقية"

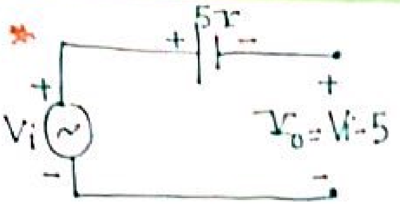
Drawing:-



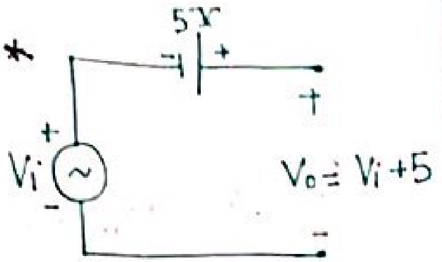
"Clamper Circuit".

"Summary For Clipper Circuit In slides" → ......

* Clamper Circuits:-



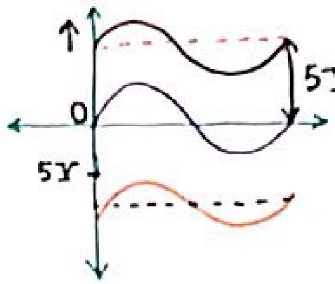
or



- ولكن المشكلة لا يوجد دائماً بطاريات بفولتية محنية فلذلك نستعين بال diodes circuits.

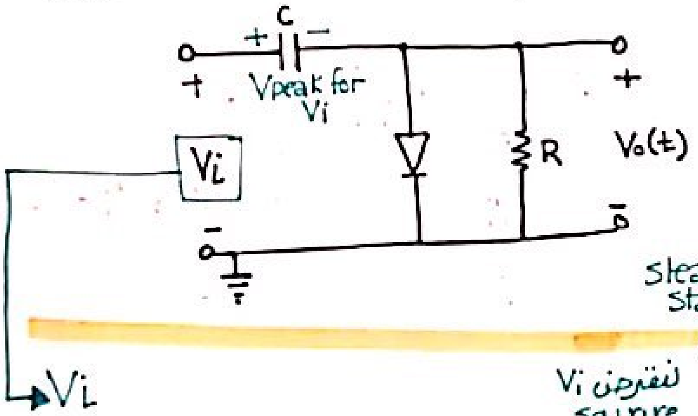
ملاحظة: كان ال Clipper يقيم جزء من ال Circuit ولغير بشكلها ولكن ال clamper هو عبارة عن سيركت يوخذ ال waveform ويعملها shift (لفوق أو لتحت)

EXP: /Clamper/ shifting (DC OFFSET):-
(Clamping)



- peak to peak not changed.

-We'll USE CIRCUIT Clamper:-

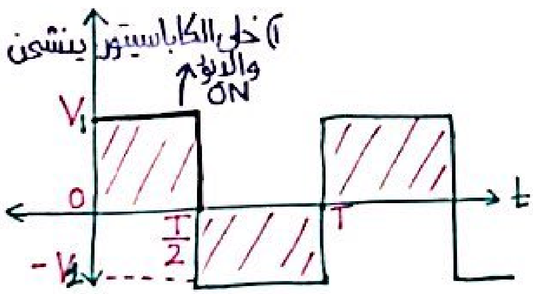


*ملاحظة:-

1- ال Capacitor موجود مع Resistor وشبك معها مصدر فولتية فال Capacitor راح ينشحن وراح سيستغرق وقت يعتمد على time constant ← $\tau = RC$ ولقيد بالعادة لـ 5τ لتوصل الدارة لـ steady state وكل ما كانت τ صغيرة تتم عملية الشحن بسرعة.

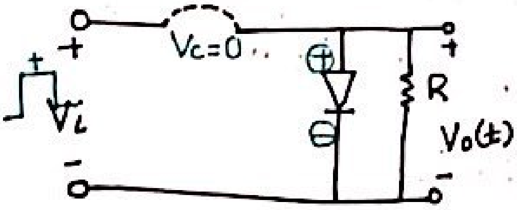
2- راح نشحن ال Capacitor بسرعة ولشحنة تعادل ال DC shift وبعد ما تشحنه وكأنه بطارية و كأنه ما راح تتفرغ وإذا به تتفرغ راح تكون طويلة وذلك τ لازم تكون كبيرة.

نفترض Vi square wave



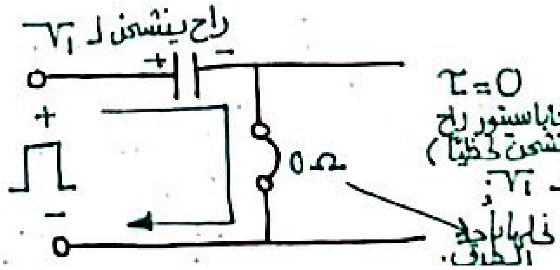
$V_c(0^-) = 0V$ "short circuit"
$V_c(0^+) = 0V$ "short circuit"

نفترض بالبداية ال capacitor يكون غير مشحون

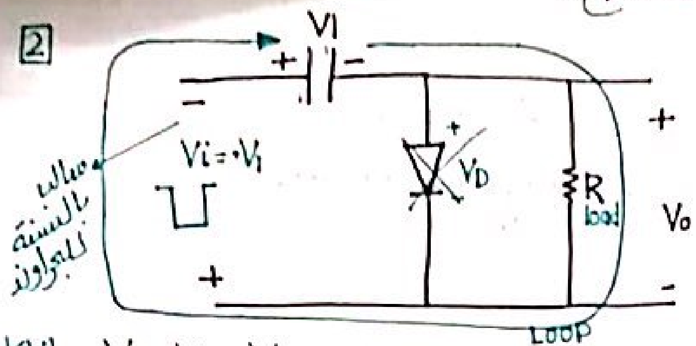


1

DON → "short circuit" "FB"



- بعدما ينشحن الـ Capacitor كيف الدارة ستستجيب؟
وشو راح يصير بالـ Diode؟



KVL: $V_1 + V_1 + V_D = 0$

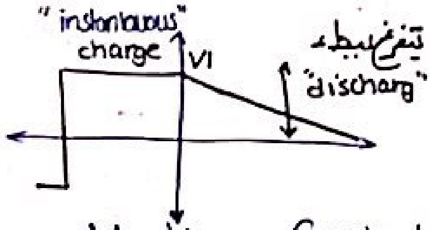
V_D على الدايود: $V_D = -2V_1 < 0$

1) Diode OFF "Open circuit"

2) Capacitor → حيبلش يتفرغ من خلال الـ Loop.

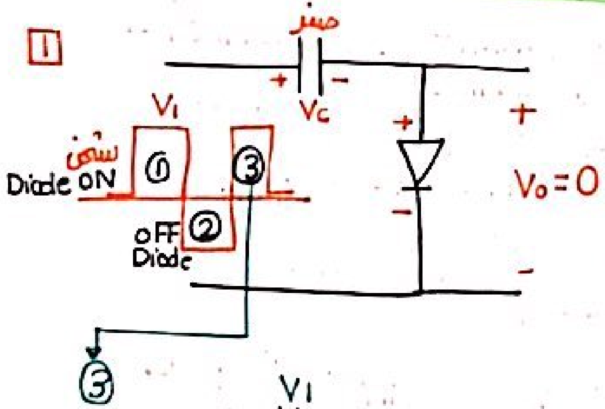
$\tau = R.C \rightarrow$ If $R\uparrow\uparrow\uparrow \rightarrow \tau\uparrow\uparrow\uparrow$ (فصار راح يتفرغ ببطء)

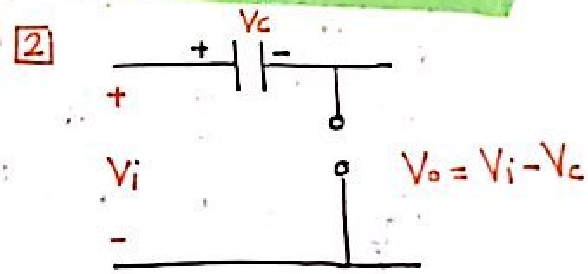
تفريغ discharg.

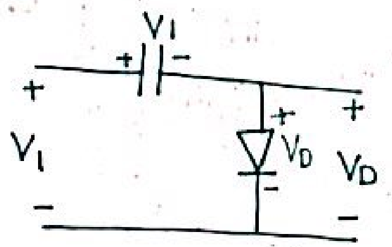


$V_C = V_{avg} \approx$ Constant

$C \approx$ Battery.







KVL → $V_1 - V_1 - V_D = 0$

$V_D = 0$

"Diode OFF" → على طول بس أول مرة تشحن

$V_{out} = V_i - V_c$.

ملاحظة: أهم شي أوجد شحنة الـ Capacitor وشو الـ Polarity وشو مقدارها؟

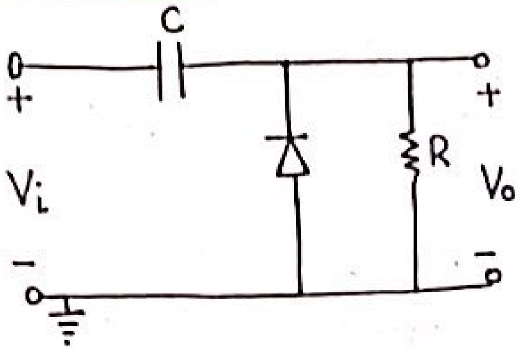
① V_c? ∿ ⊓ N ← بدنا نشوف متى الـ Diode ON بعدها بنجد الـ Polarity
الجزء الموجب أم السالب؟

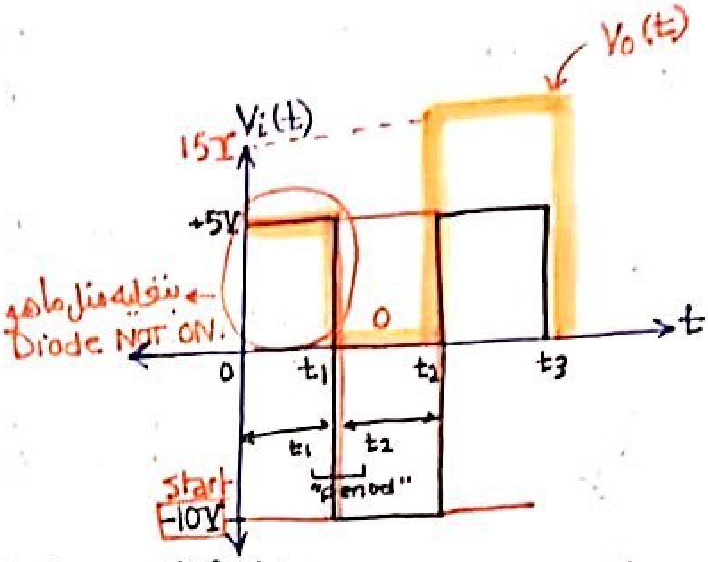
② $\overset{+}{}|\,|\overset{-}{}$ V_c or $\overset{-}{}|\,|\overset{+}{}$ V_c → ③ $V_o = V_i \pm V_c$

.4.

PART(2):-

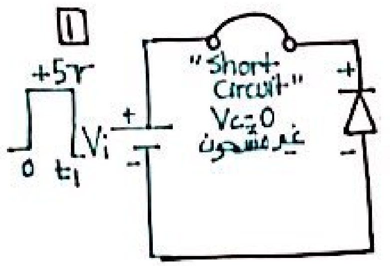
* EXAMPLE:-





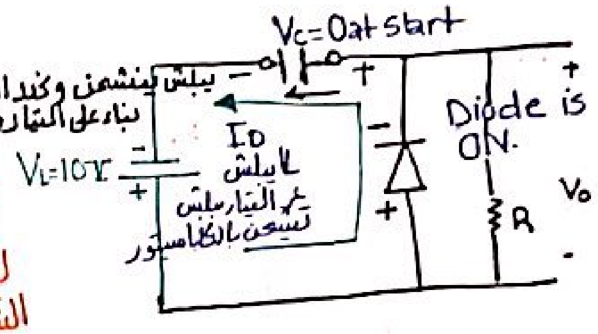
Clamper Circuit / Capacitor in series between V_i & V_o:-

1

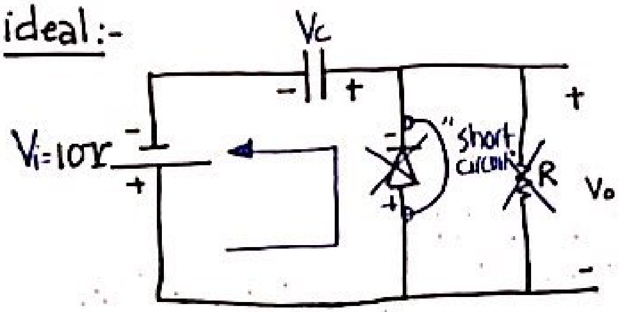


Diode is not ON
هون لما بلش من هون
الـ analysis والـ wave form periodic
ولكن بلشنا من -10V
وليس +5V.

نبدّل لمضربابة الشي. DIODE ON



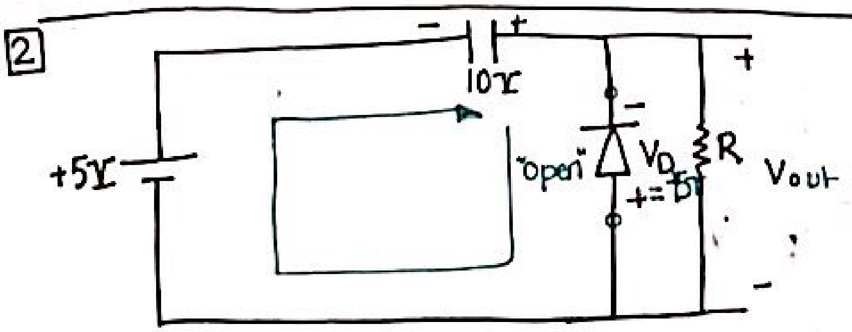
ideal:-



KVL: $V_c = 10V$

$V_o = 0V = V_i + V_c = 10 + 10$

2



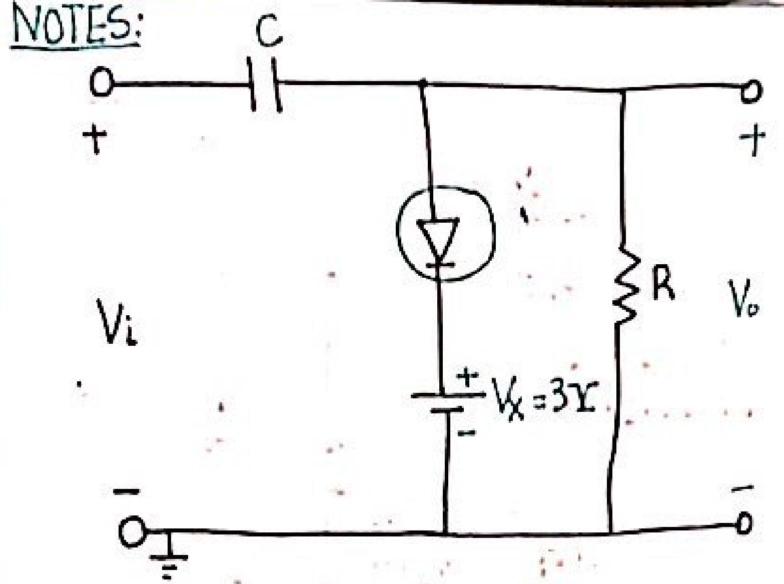
KVL: $V_D = -15V \rightarrow$ Diode OFF

$V_{out} = 15V = V_i + V_c$

* الرسمة في السلايدات الـ Steady State.

Note: $\tau = R \cdot C$ $> 10(t_1 + t_2)$ period of waveform.

NOTES:



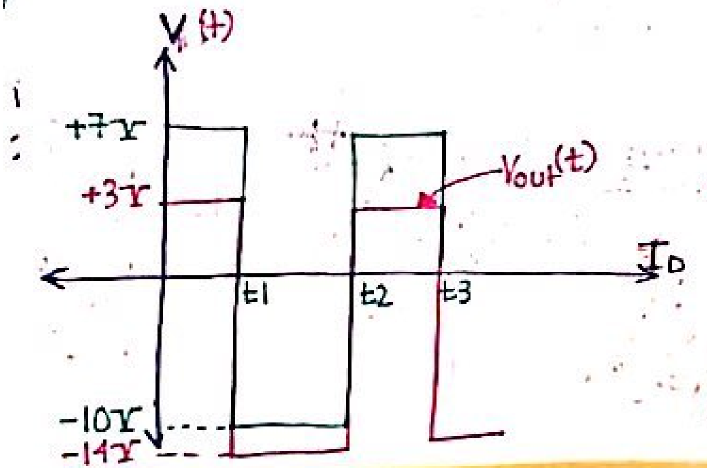
① إذا الـ diode لتحت ← I_D مرور التيار والـ Polarity

$V_o = V_i - V_c$ (shift down)

② إذا لفوق → I_D مرور التيار

$V_o = V_i + V_c$ (Shift UP)

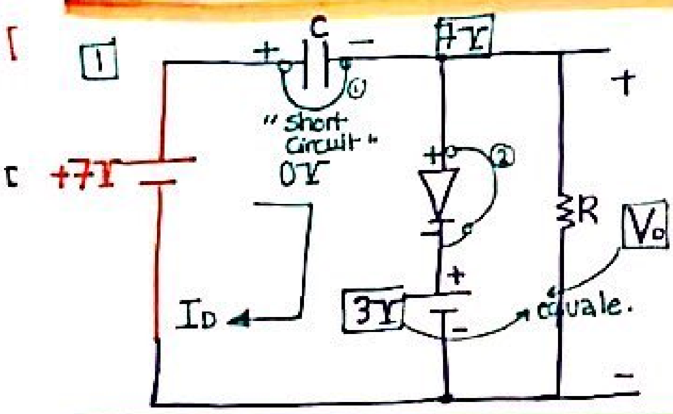
③ بدنا نطلع مقدار الـ Shift؟ ، وكمان فهمنا مصدر جديد كيف نحل Analysis؟



* peak-to-peak = 17 the same

7 → 10

3 → 14



Diode is ON

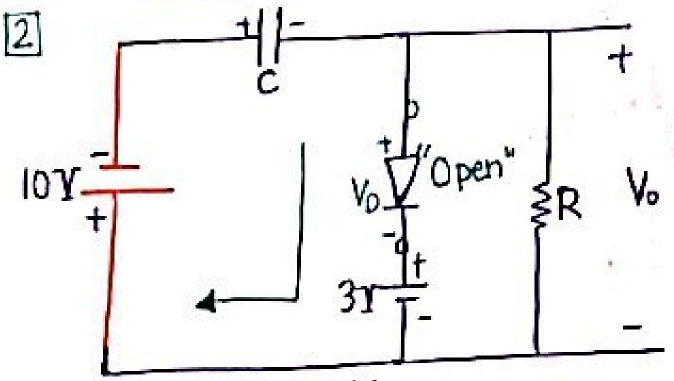
$V_A = 7 > V_K = 3$ →

KVL: $7 = V_c + 3$

$V_c = 4V$

$V_{out} = V_i - V_c$ (Diode short) خلص ثابتة وتحمل مشحون.

$= 3V$



KVL → $10 + V_c + V_D + 3 = 0$

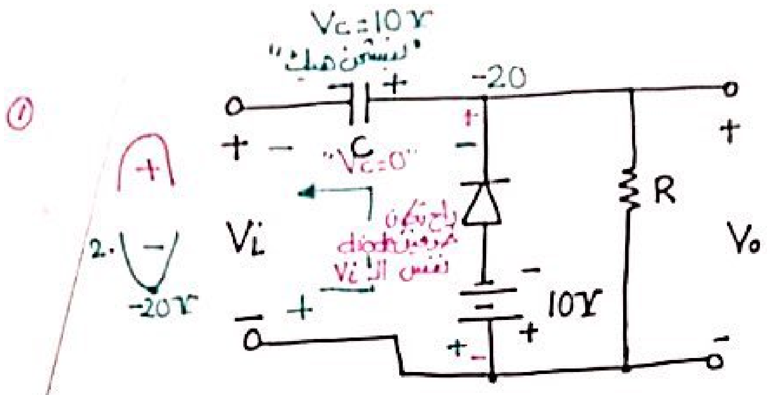
$V_D = -17 < 0$ → Diode is off → $V_o = V_i - V_c$

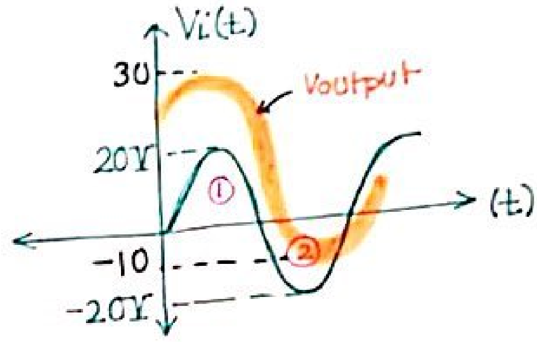
$= -10 - 4 = -14V$

* EXAMPLE:- Biased Clamper Circuits: (HW Exercise)

- إذا الإشارة Sinusoid الـ Capacitor راح يوخذ وقت ليشحن والـ Capacitor بيشحن الـ positive أو negative peaks.

- هل بتخلي الـ diode الجزء الموجب منه؟ ON/OFF





KVL: $10 + V_c - 20 = 0$

$V_c = 10V$

$V_o = V_i + 10$

"إذا الـ diode لفوق فهو بيعطي نفخة الـ capacitor rise للinput"

* Summary of Clamper Circuits in Slides:-

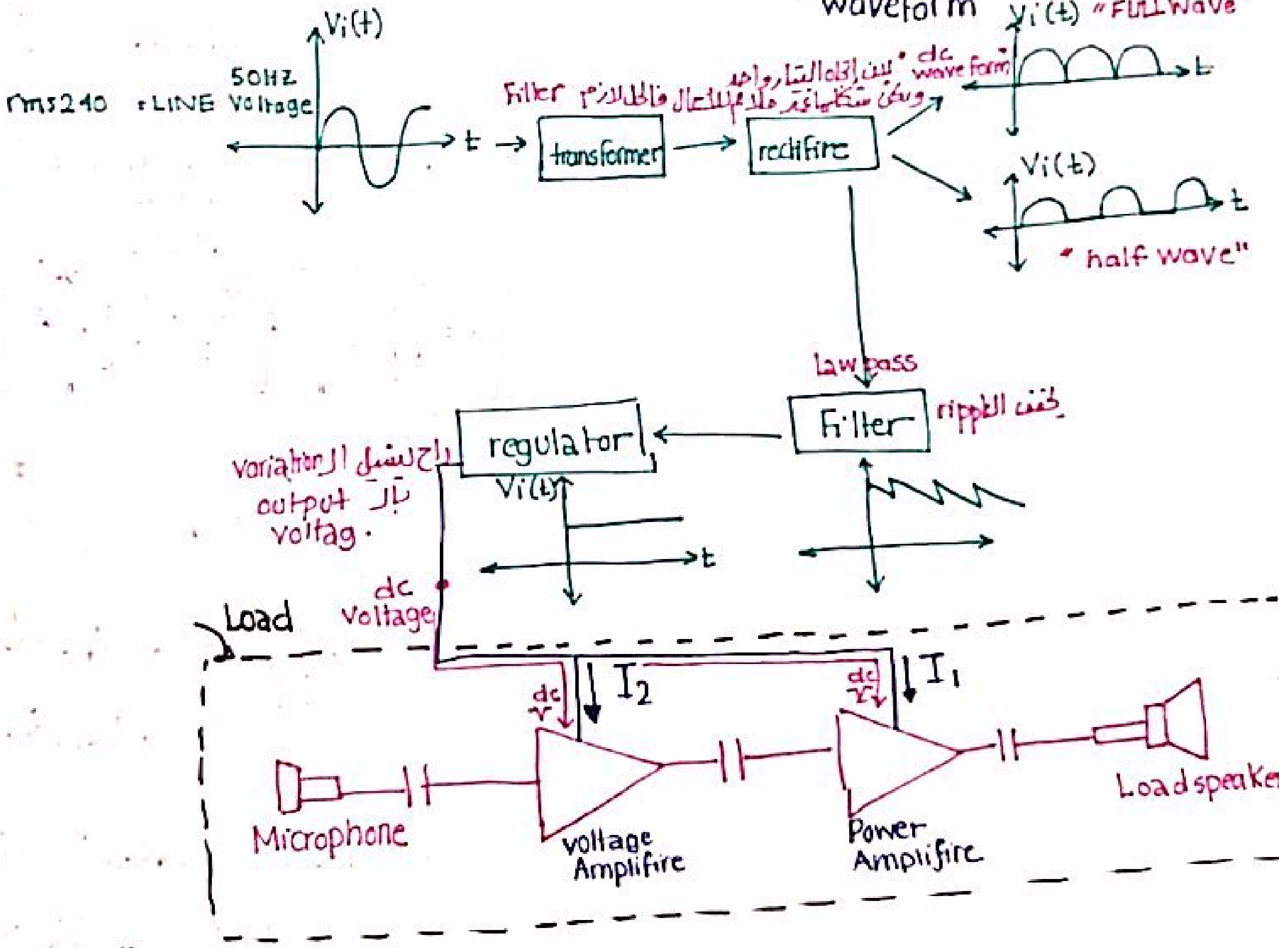
L5: (9-6-2020): Rectifiers :-

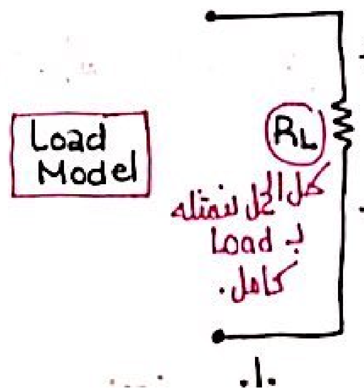
- تطبيق آخر من تطبيق الـ diode وهي عملية تحويل الـ voltage من الـ ac→dc وهو ما يسمى Rectifire.

*DC Power Supply :-

1- لا نشحن التلفون أو اللابتوب بتوصيلها مع ac من مصدر كهربائي في الـ dc power supply بتحول من sinusoid (ac) لـ dc ، هل هي بتحوله لـ 10V بالزبط؟ راح نحكي لاحقاً.

2- بيجينا من الشركة 220V V_{Rms} بدنا نقلله لـ 5V أو 10 فأول شيء لازم نقلل الـ Amp الـ Voltag فهاد بعمله device يسمى transformer ، وبعد هيك يتم تحويل الـ sinusoid (ac) لـ rectifier.

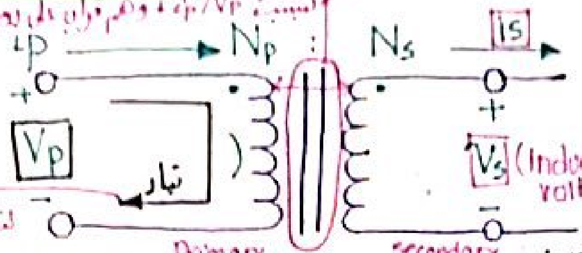




$$\frac{V_{DC}}{I_1 + I_2}$$

Designing a power supply.

[I] Transformer:-



الحقل المغناطيسي بسبب i_p/N_p وهم مزابين بعض وملفوفين على نفس الـ core.

تولد مرور تكوين حقل مغناطيسي

(N_p = عدد اللفات تبعهم) Primary ملف

secondary ملف (عدد اللفات اجنا بتبعهم N_s)

magnatic core ملفوف على

محولة من Ferrite، تزيد من الـ effeciency للـ Transformer، وذلك من خلال الحفاظ على تركيز الحقل المغناطيسي من التشتت

1- هو عبارة عن device بشتغل مع ac voltages وما بشتغل مع dc voltages.

2- power → secondary / primary هون بنعتبر الـ Transformer إنه ideal بحيث على 100W على الـ input رح يطلع 100watt على الـ output.

$$i_s V_s = V_p i_p$$

3- primary voltag والـ secondary voltag بنعتبر إنه ما في بينهم (phase shift) ← inphase.

4- primary terms والـ Secondary terms وظيفتهم مثلاً عندي $V_p = 100V$ بنحولها لـ $10V$ بنلعب بعددهم.

$$n = \frac{N_s}{N_p} \quad , \quad \frac{V_p}{V_s} = \frac{N_p}{N_s} \quad , \quad \frac{i_s}{i_p} = \frac{N_p}{N_s}$$

relation:-

$$V_s = n V_p \qquad i_s V_s = V_p i_p$$

* لو بدي $V_p > V_s$ ← $V_s = \frac{N_s}{N_p} . V_p$

بخلي $N_p > N_s$.

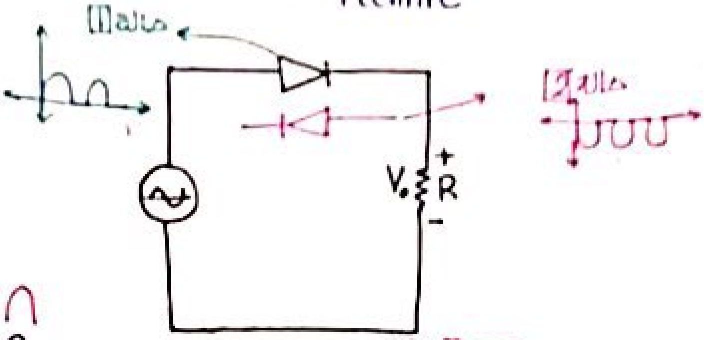
5- إذا $N_p = N_s$ ← Unity Transformer.

إذا $N_p > N_s$ ← down Up Transform.

إذا $N_p < N_s$ ← Step Up Transformer. (ممكن بدي أرفع الـ Volt)

* Rectifier:-

- كيف تعمل halfwave rectifire ؟



1 - $V_i > 0 \rightarrow$ D ON $\rightarrow V_o = V_i$

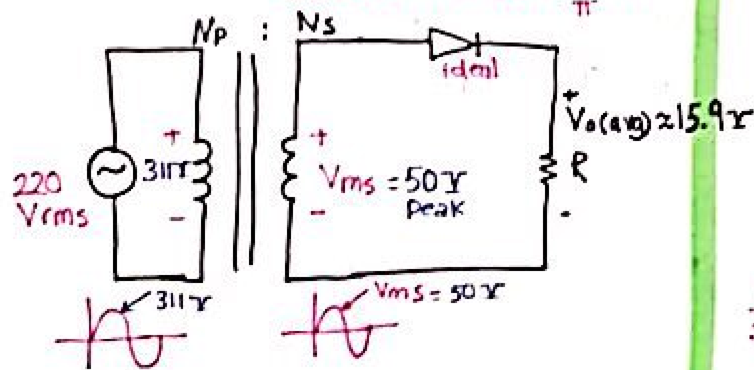
2 - $V_i < 0 \rightarrow$ D OFF $\rightarrow V_o = 0$ V

$V_o = 0$

$V_o = V_i$

- لو أنا دخلت 100V peak ← 31.8 V_{avg} لو مابدي هاي القيمة
بستعين في Transform وبستعين ب N_s و N_p لتطلع الشكل إلي بدي إياه.

* $\frac{V_m}{\pi}$ أما الناتج volt على diode.



$N_p : N_s$?

- $V_{o(avg)} = \frac{V_{ms}}{\pi}$

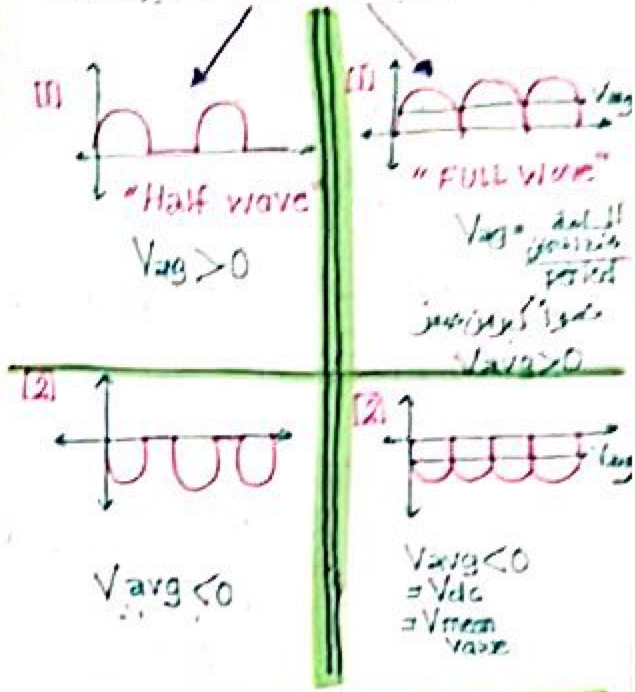
$V_{ms} = 15.9 * 3.14 = 50$ V.

- $\frac{V_P}{V_S} = \frac{N_P}{N_S}$

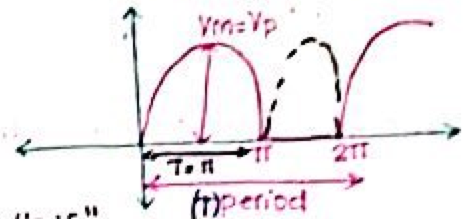
$\frac{220\sqrt{2}}{50} = \frac{N_P}{N_S} = \frac{311}{50} = 6.22$

62] [10
6] [1
622] [100

- ممكن أوضح ال waveform وحولها:



ملاحظة: إذا بدي أوجد V_{avg}:



"Half"

• $V_{avg} = \frac{1}{(T)} \int_0^{2\pi} V_m \sin wt \, dt$

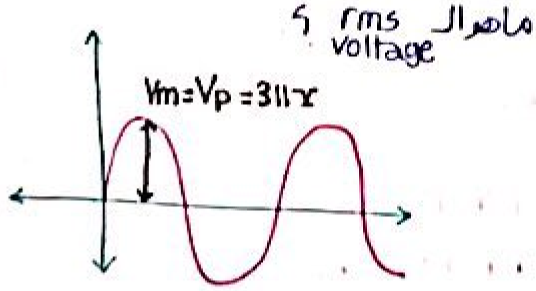
تكملة بال slides. $V_{avg} = \frac{1}{T} \int_0^{\pi} \sin wt \, dt \rightarrow V_{avg} = 0.318 V_m$

100 peak → 31.8 V_{avg}

• "FULL Wave"

• $V_{avg} = \frac{1}{(T)} \int_0^{\pi} V_m \sin wt \, dt$, $T = \pi$

- ماهو ال rms voltage ؟



- $V_{rms} = \frac{V_m}{\sqrt{2}}$ "For sinwaves"

- 220 $V_{RMS} \longrightarrow V_P = 220 * \sqrt{2}$
$= 311$ volts.

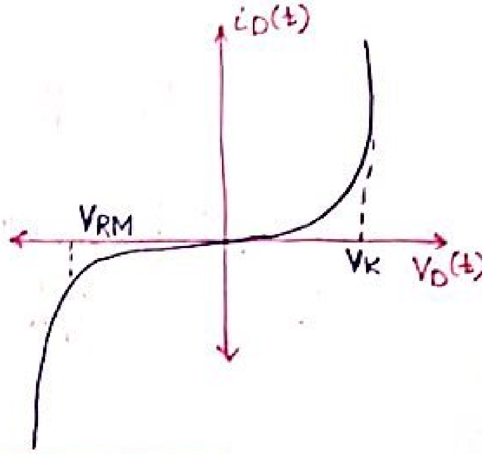
- لما بدي أختار الـ Diode المناسب لهذه الـ Circuit كيف بدي أختاره؟

[1] I_{FM} → Maximum Forward Current.

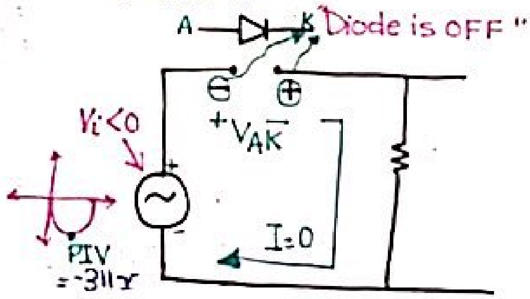
[2] V_{RM} → Maximum reverse Voltage.

[3] PIV → Maximum Peak Inverse Voltage.

$PIV = V_{RM}$.



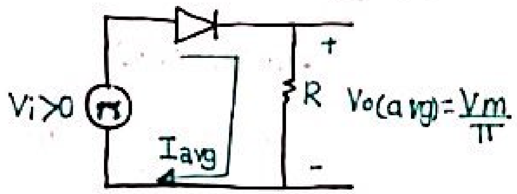
- ماهو مقدار PIV للـ Diode في حالة الدارة تابعة الـ Rectifire Half wave ؟
(Peak Inverse voltage).
بالسالب



* $V_{AK} = PIV = -V_m = -311V$

* لازم أجيب diode يستحمل reverse voltage = 311V.

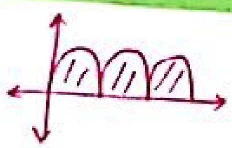
- آخر هو الـ Parameter average voltage ؟



* $I_{avg} = \frac{V_m}{R\pi}$ (diode current).

* FULL Wave Rectifier:-

- هي سيركت تعطيني

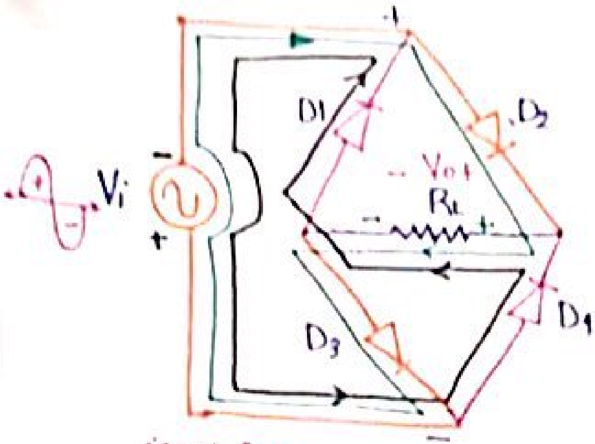


2 Kinds:-

1. Bridge Full wave.

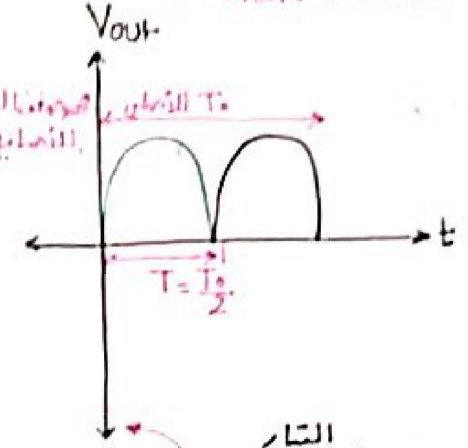
2. Center Tapped Transformer FULL-wave.

* Bridge / FULL Wave form :-



input from AC source or Transformer.

" FULL Wave rectifire "



1. يمين ← للشمال التيار

2. الشمال ← لليمين

If $V_i > 0$ (+), D1 & D4 OFF, D2 & D3 ON (Short Circuits), عبر التيار ويعمل Voltag drop الـ resistor, Voutput

2. Diode are short Circuit.

* الرسمات والمنحنيات بالتسلايدات

If $V_i < 0$ (−), D1 & D4 ON, D2 & D3 OFF, التيار نفس الإتجاه على المقاومة وهنا يعني أنه dc الـ Voltage, Voutput $= -V_i$

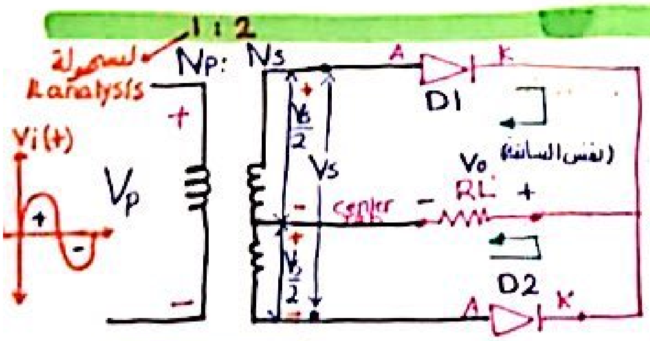
NOTE:

- $V_{o(avg)} = \frac{2V_m}{\pi} \Rightarrow V_{dc} = 0.636\, V_m$.

- لنحسب الـ PIV ؟ للحالة الأولى وهي الـ Vi>0 تكون . PIV = −Vm (خالسلايدات موجودة)

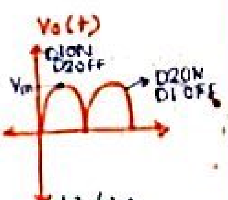
* Center Tapped Transformer FULL-Wave :-

- التنين بعطو نفس الـ OUTPUT Bridge & Center Tapped.



$$\frac{V_p}{V_s} = \frac{N_p}{N_s}$$

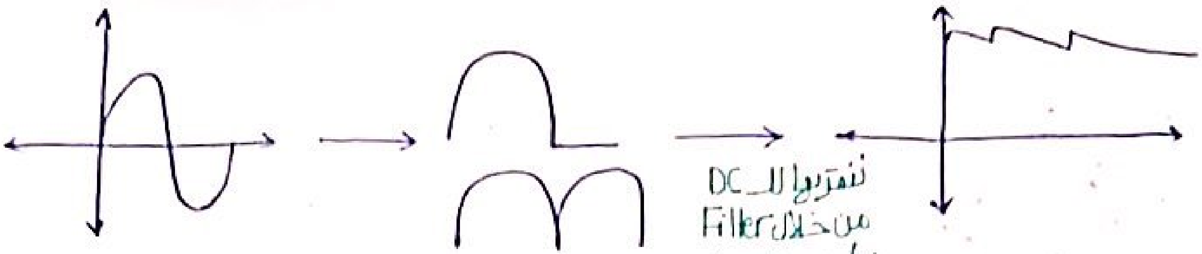
→ نفس العلاقة ولكن الفرق أن الـ Voltag تبقسم



هنا مثال السلايدات Np:Ns 1:2 ولكن ممكن يتغير حسب السؤال بشكل عام.

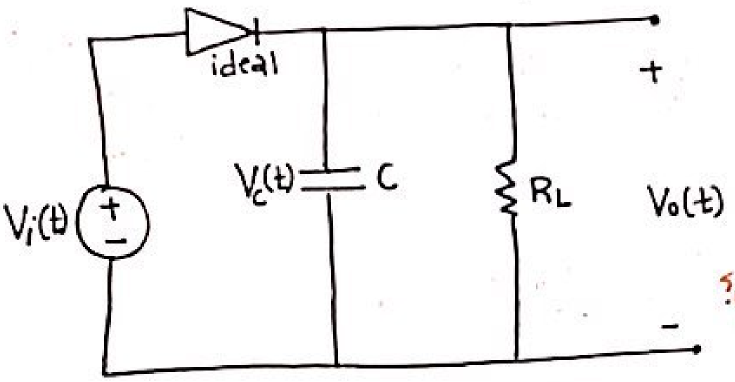
- هو عبارة عن Primary للـ Transformer و secondary ولكن محول بشكل خاص بعد ما تلف نص اللفات توخذ نقطة وهي ما تسمى (Center Tap)

PIV ⊟ From Slides ⇐ 2Vm الموجودة على نص الـ secondary



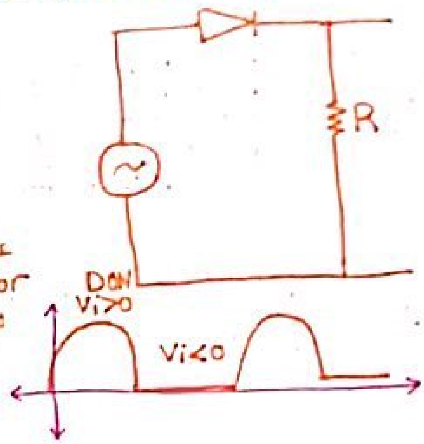
لنقربها للـ DC
من خلال Filter
لكون LOW PASS
عبور جزء الـ dc
ونعمل rejection لـ ripple .
(Capacitor) راح نعملها.

Simplified Circuit:-



عند إضافة Capacitor ماذا سيحصل؟

علم Analysis لهاد الدارة الكهربائية:

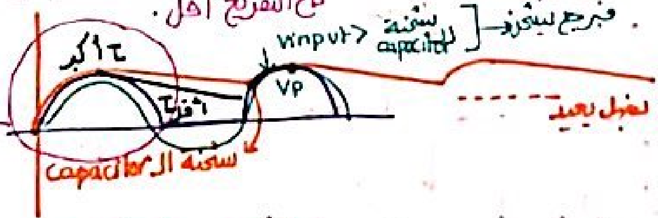


- فالبداية الكاباسيتور غير مشحون فلما يلبس الـ voltage على Vi يزيد يبلش ينشحن.

- لما يوصل Vp راح يصير الـ Capacitor مشحون بـ Vp
- بس بعدها راح ينزل الـ V<Vp.

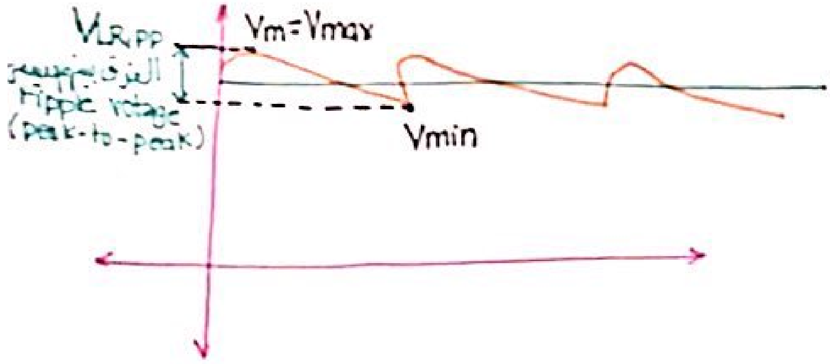
← فبالتالي الـ diode راح يصير عنده ويصير OFF ويصير الدارة مفصوله عن إلى قبل.

- بعدها الـ Capacitor راح يبلش يتفرغ لإنه parallel مع مقاومة بـ rate يعتمد على τ كل ما كبرت τ تزيد كل ما كان الـ rate تاع التفريغ أقل.



(احنا يعني ينزمله)

- فبيصير dc وكإنه الـ cicle الأولى. ونوخذ فقط الـ steady state بعد

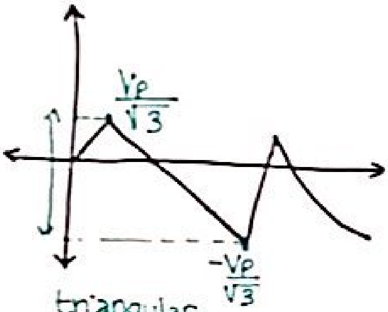


$V_{avg} = V_m - \frac{1}{2} V_{LR,PP}$

or $= V_m + \frac{1}{2} V_{LR,PP}$

$- r\%$ (ripple factor) $= \frac{\text{RMS RIPPLE}}{V_{avg}} * 100\%$

$\text{RMS RIPPLE} = \frac{V_{Lr,pp} \text{ (Peak-to-Peak)}}{2\sqrt{3}}$



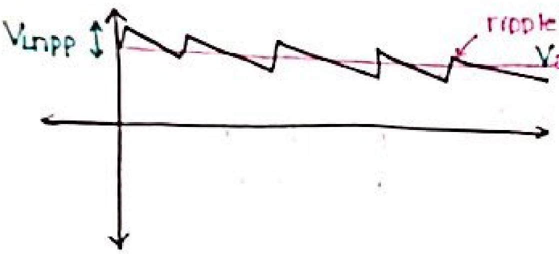
triangular
(saw tooth)

6: Filters and Ripples:- (10-6-2020) : PART 1:-

- أهمية الفلتر تحويل ال signal من ال rectifire لـ (dc).
- بدنا C صغيرة عشان discharge بطيء ونقرب أكثر لـ (dc).

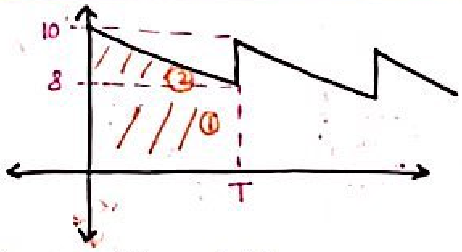
- فال dc power supply لنقيس هالفلتر وإمكانيتها بإعطائنا قيمة قريبة من ال dc بنستخدم ال ripple factor

هنحتاجها أمعظمها $r\% = \frac{\text{RMS (ripple of output voltage)}}{\text{average value of output}} \times 100\%$ $\quad \text{RMS Ripple} = \frac{V_{LRipp}}{2\sqrt{3}}$ غالبا حلو نحفظه ما يكون



$V_{avg}\text{value} = V_m - \frac{1}{2} V_{Lr,pp}$
$= V_{min} + \frac{1}{2} V_{Lripp}$

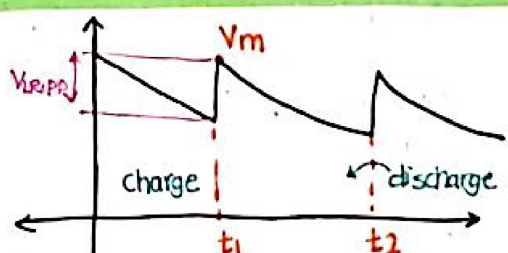
* EXAMPLE:



average output voltage $= V_m - \frac{1}{2} V_{Lr,pp}$
$= 10 - \frac{1}{2} \cdot 2 = 9V.$

الطريقة الثانية في ال slides.

* Ripple Factor:-



- ليشحن بسرعة ويفرغ ببطء

period = discharge + charge للأماي

Capacitor Discharge → $V_L(t) = V_m e^{-\left(\frac{t_2 - t_1}{RC}\right)}$

إذا عرفتها بتعرف كلشي. ← $V_{Lr,pp} = V_L(t_1) - V_L(t_2)$

$= V_m - V_m e^{-\left(\frac{t_2 - t_1}{RC}\right)}$ $\quad$ x كتير صغيرة لأن C كبيرة

$= V_m \left(1 - e^{-\left(\frac{t_2 - t_1}{RC}\right)}\right)$ $\quad$ USING $e^{-x} \approx 1 - x$

$= V_m \left(1 - \left(1 - \left(\frac{t_2 - t_1}{RC}\right)\right)\right)$

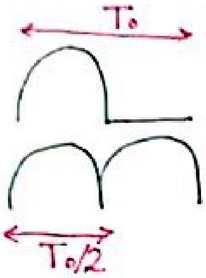
$= V_m \left(\frac{t_2 - t_1}{RC}\right) \longrightarrow \frac{V_m T}{RC} = \frac{V_m}{f RC} = V_{Lr,pp}$ معطى

* $V_{dc} = V_m - \frac{1}{2} V_{R,p\text{-}p}$

$= V_m \left(1 - \frac{1}{2 f_o RC}\right)$

* $(V_{L,r})_{RMS} = \frac{V_m}{2\sqrt{3} f_o RC}$

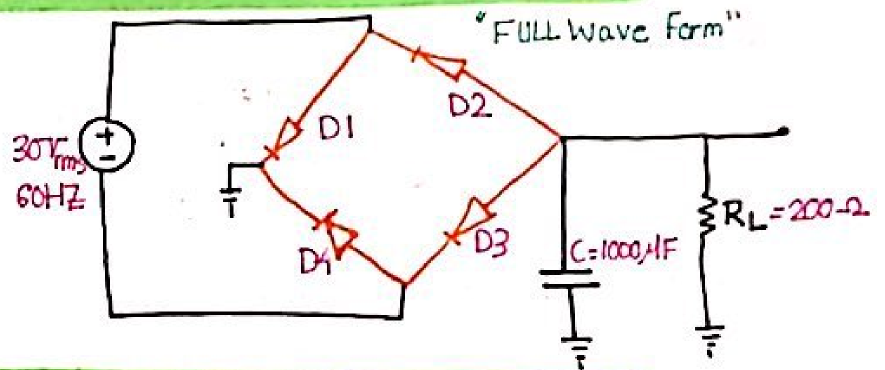
- كل الexpressions كانت لل halfwave ولكن لو بدي أعمل ل FULLWave بضاعف الـ freq.



$\longrightarrow V_{LR\text{-}P\text{-}P} = \frac{V_m}{2 f_o RC}$. - الـ FULL wave بعطيني نص الـ ripple لل halfwave بنفس الكاباسيتور والريسيستور والفولتيج سورس.

* EXAMPLE:-

- FIND the ripple factor ($r\%$).
- Input = 30 V RMS.
- F = 60 HZ.



SOLUTION: $r\% = \frac{\text{RMS RIPPLE}}{V_{avg}} \cdot 100\% = \frac{0.51}{41.51} \cdot 100\% = 1.2277\%$.

بالعادة أقل من 5%.

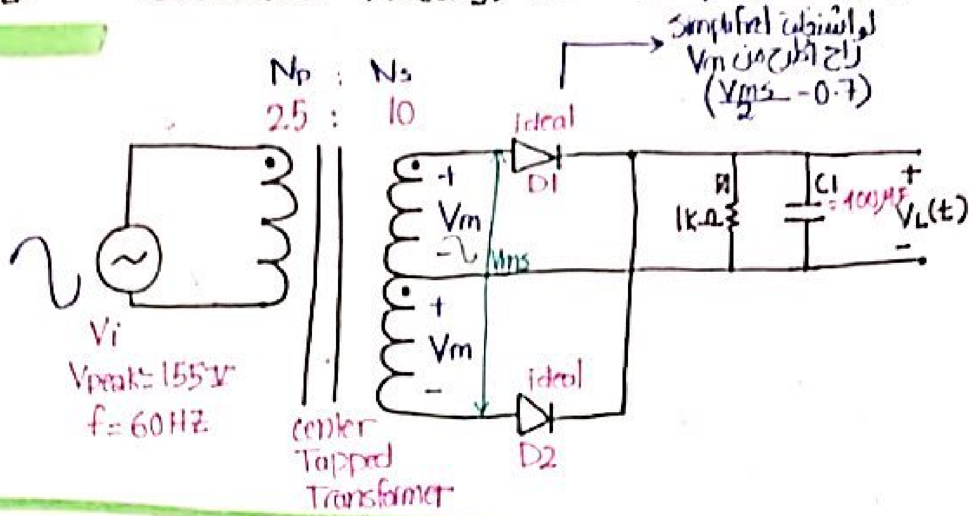
$V_{LRMS} = \frac{V_{Lr,p\text{-}p}}{2\sqrt{3}} = 0.51\ V_{rms}$

$V_{LR,P\text{-}P} = \frac{V_m}{2 f_o RC} = \frac{30\sqrt{2}}{2 * 60 * 200 * 1000 \times 10^{-6}} = 1.7677\ V$

$V_{avg\,(dc)} = V_m - \frac{1}{2} V_{LR\text{-}P\text{-}P}$

$= 30\sqrt{2} - \frac{1 \cdot 30\sqrt{2}}{2 * 2 * 60 * 200 * 1000 \times 10^{-6}} = 41.51\ V$

* EXAMPLE:- Calculate VL(avg) and r% if C = 100 μF :-



SOLUTION:

$\frac{V_{ms}}{2}$ هو الناتج عن ال output

$$V_{L\,avg} = V_m - \frac{1}{2} V_{Lr,p-p}$$

[1] $$V_{ms} = \frac{N_s}{N_p} \cdot V_{mp} = \frac{10}{2.5} \cdot 155 = 62\,V$$

$$V_{L\,avg} = \frac{V_{ms}}{2} - \frac{1}{2} V_{LR,p-p}$$

$$= \frac{62}{2} - \frac{1}{2}\left(\frac{V_m}{2f_oRC}\right)$$

$$= 31 - \frac{1}{2}\left(\frac{(V_{ms}/2)}{2f_oRC}\right)$$

$$= 31\left(1 - \frac{1}{2 \times 60 \times 1000 \times 400 \times 10^{-6}}\right) = 30.67\,V.$$

$$r\% = \frac{V_{LR,RMS}}{V_{avg}} \cdot 100\% = \frac{\frac{0.32}{2\sqrt{3}}}{30.67} \cdot 100\% = 0.3\%$$

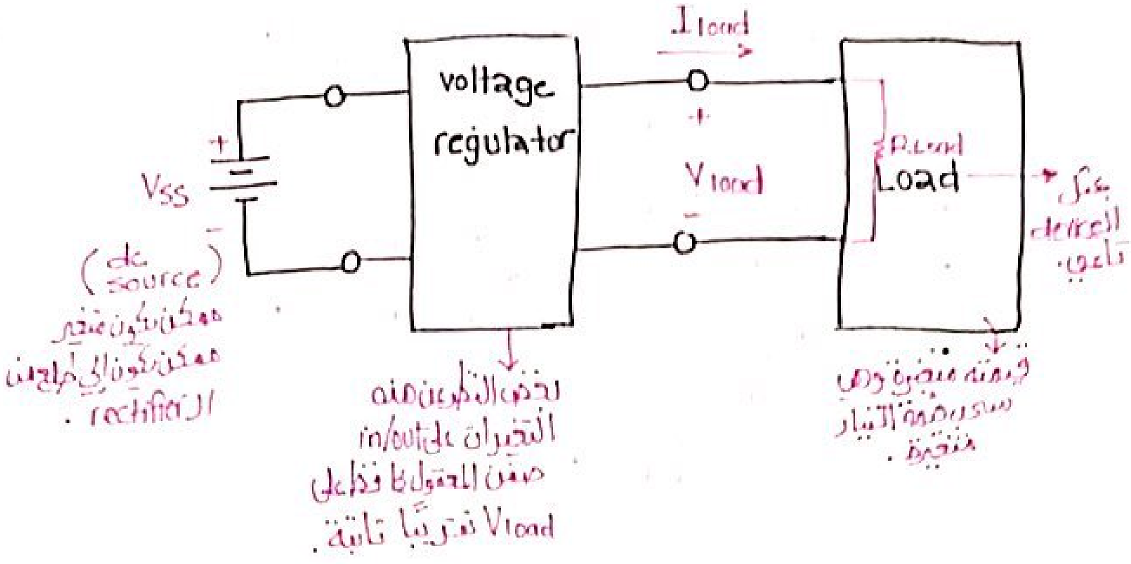
L5 + L6.1 (PiecePise).

PART(2) :- آخر تطبيق من تطبيقات ال diodes غير regular.

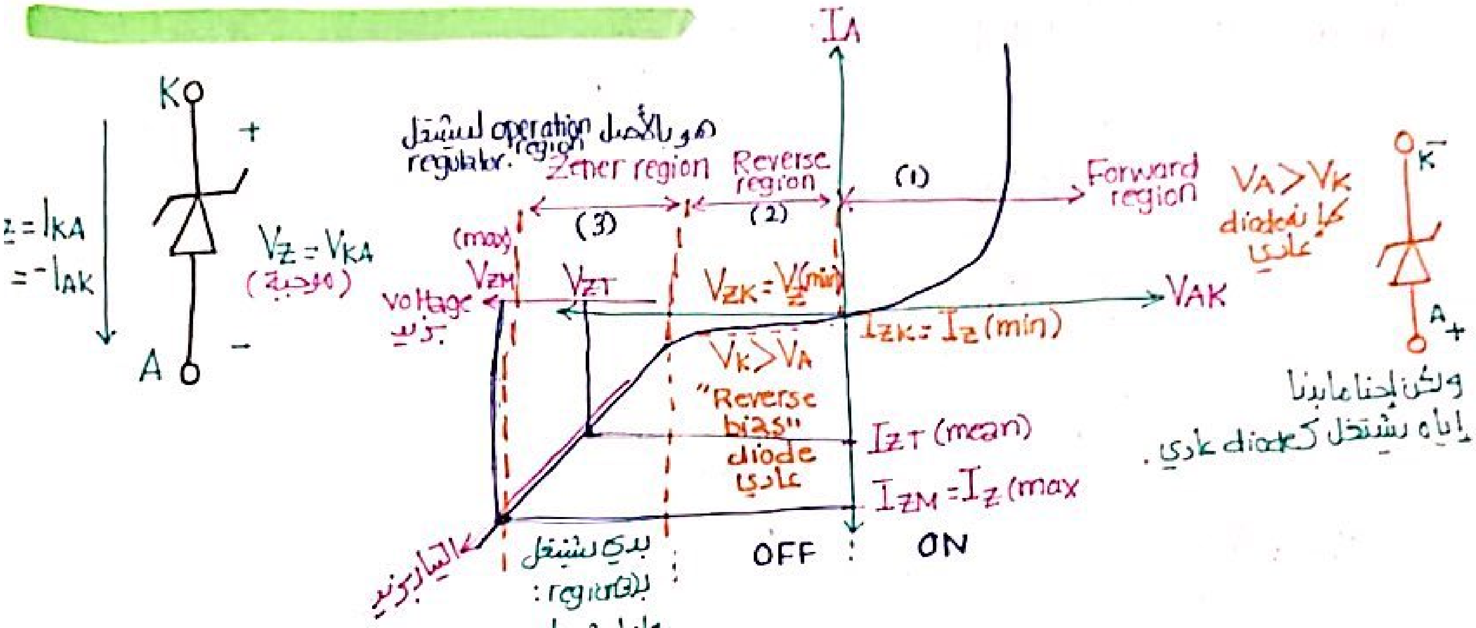
* Zener Diods :- (voltage regulator)

- هو السيركت راح توخذ الفولتيج إلى خرج من rectifier + Filter وتخلي ثابت وتشيل ال ripple منه أو تقلل منه قدر الإمكان.

- هي سيركت تحافظ على ال output تبعها بغض النظر ما يحصل تغيرات داخل الدارة على ال input voltage أو ال Load current.



* Zener-Diode V-I Curve :-



بدي يشتغل بالـ region(3) :

وإلها شروط

[1.] لازم التيار

$I_{Z(min)} < I < I_{ZM(max)}$

[2.] الفولت بين الـ K و A :

$V_{ZK} < V < V_{ZM}$

} Zener voltage regulator.

NOTES:-

* $I_Z < I_{ZK}$ (Zener acts as "Open Circuit").
* $I_Z > I_{Z(max)}$ (Zener will damaged).

NOTES:-

Short circuit ← ON ← region(1)-1 → ideal / → simplified 0.7.

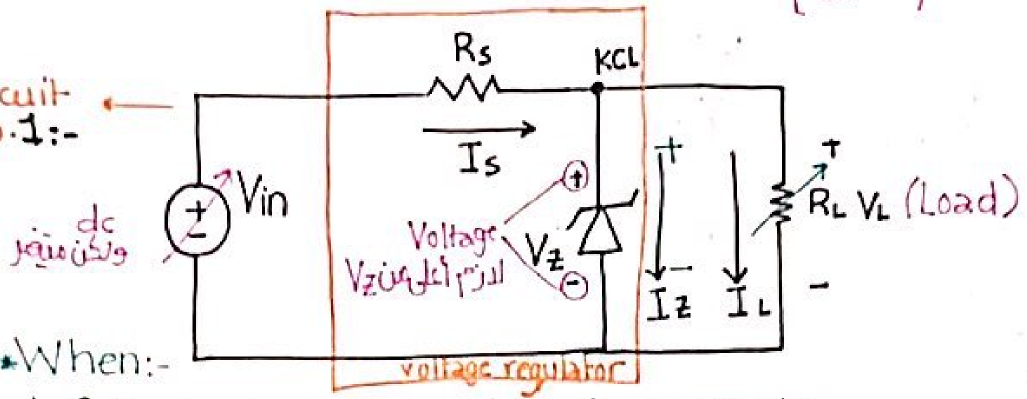
Open Circuit ← OFF ← region(2) 2

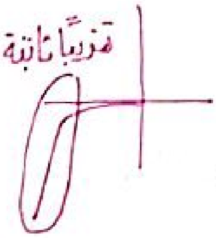
* Zener Diode Operation & Models:-

- region(3) → V_Z (Voltage Source) instead of:
(breakdown) ON — or V_Z (Voltage Source) + R_Z {مقاومة صغيرة}.

فقط هذه السركت للـ Zener

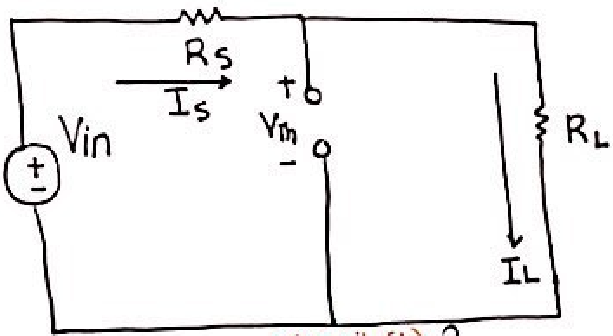
Circuit (1).1:-





*When:-

1. Cathod Must be positive than anode.
2. $V_{Th} \geq V_Z$



circuit (1).2

3. $I_Z > I_{Zmin}$
4. $I_Z < I_{Zmax}$

Circuit (1).2:-

$$V_{Th} = \frac{R_L}{R_L + R_S} \cdot V_{in} \geq V_Z \text{ (data sheet)}$$

تتحقق بالمساوي

Circuit (1).1: (KCL)

$$I_S = I_Z + I_L$$

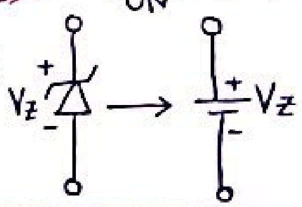
---

*NOTE:

region (3):

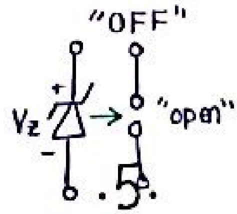
1. Ideal

"ON"

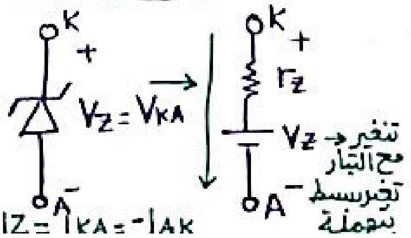


$V_Z > V > 0$ or

"OFF"

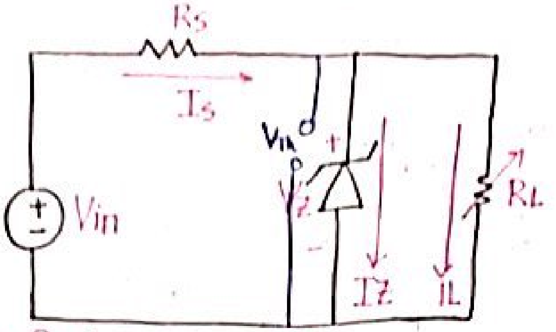


2. Simplified:-



* Fixed Vin , Variable R_L :-

- في عندي Vin و R_L متغيرين فأنا بعيار وقيمة الـ min & max لكل وحدة بتغير وحدة وبثبت الثانية.



R_L Min & R_L Max? (?< R_L <?)
ولكن شرط عمل الـ Zener كـ Voltag regulat.

[1] $V_L = V_Z = \frac{R_L}{R_L+R_S} \cdot V_{in}$

$V_{th} \geq V_Z$

$V_{th} = V_Z$

بنعرفوا R_L (min) $\frac{R_L}{R_L+R_S} \cdot V_{in} = V_Z$

$V_{in} \cdot R_L = V_Z R_L + V_Z R_S$

$V_{in} > V_Z$ دائماً ← $(V_{in} - V_Z) R_L = V_Z R_S$

We find $R_{L(min)}$ → $\boxed{R_{L\,min} = \frac{V_Z \cdot R_S}{V_{in} - V_Z}}$

---

[2] to Find $R_{L(max)}$:

V_{in}, R_S, I_S, I_Z (معروفات)

* $I_{L(max)} \rightarrow R_{L(min)}$

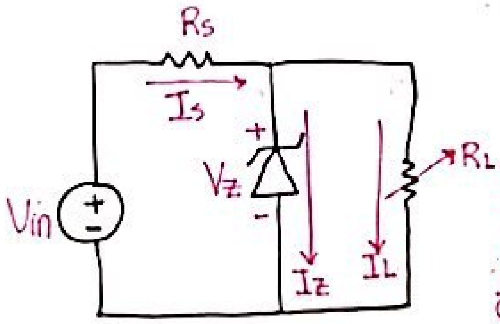
$I_{L(min)} \rightarrow R_{L(max)}$

$I_{L(max)} = \frac{V_L}{R_L} = \frac{V_L}{R_{L(min)}}$ ← ناتج ---- ①

---

* $I_{L(min)} = I_S - I_{Z(max)}$ (I_S: Const., $I_{Z(max)}$: datasheet)

$R_{L(max)} = \frac{V_Z}{I_{L(min)}}$ ---- ②

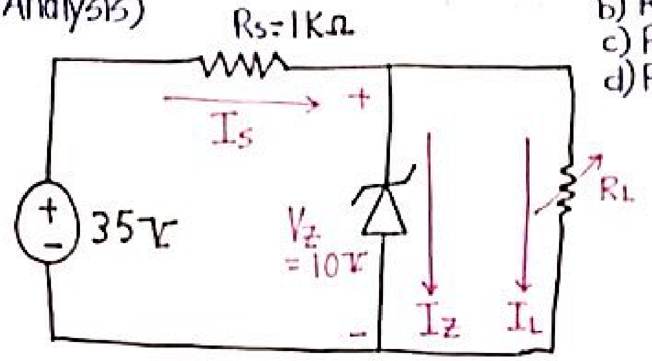


بيعطوني $I_Z > I_{Z\,max}$ (Data sheet)
لازم تكون أقل ولا تخرب
فأفرض $I_S = 100$ وراح
الـ 80A لـ I_Z و I_L أخذ 10A
إذا رجعوا الـ 10A للـ I_Z تخرب ممنوع أمرر
أقل من 20 لـ I_L وهي $I_{L(min)}$.

* EXAMPLE: FIND MODE OPERATION oF the Zener Diode? and V_L.

a) $R_L = 0.1\,K\Omega$
b) $R_L = 0.5\,K\Omega$
c) $R_L = 5\,K\Omega$
d) $R_L = \infty$

(Analysis)



- بدنا نشوف قيم R_L, R_s, V_{in} هل راح تخلي الـ diode يشتغل (regulator) ولا راح يكون open circuit او diode عادي.
فراح نبلش بالشروط.

1 $V_{Th} \overset{?}{\geq} V_Z$

USING Ideal Model:-

$$V_{Th} = \frac{R_L}{R_L + R_s} \cdot V_{in} = \frac{0.1}{0.1+1} \cdot 35 = 3.18\,V = V_{RL}$$

$3.18 < 10$ (Zener is like region "2" - Open circuit) وجوده مش مهم

2 $R_L = 0.5\,K\Omega$.

$$V_{Th} = \frac{0.5}{0.5+1} \cdot 35 = 11.67\,V > 10\,V$$ (zener is working in region (3) as voltage regulator).

$V_L = V_Z = 10\,V$ (كبداية)

1- $I_s = \frac{35-10}{1K} = 25\,mA$

2- $I_L = \frac{V_L}{R_L} = \frac{10}{0.5\,K\Omega} = 20\,mA$.

3- $I_Z = I_s - I_L = 25 - 20 = 5\,mA$.

3 $R_L = 5\,K\Omega$

$V_{Th} = 29.17\,V \gg 10$ (دور الـ regulator)

$V_L = V_Z = 10\,V$ — بشبه بين الـ max & min
$I_s = 25\,mA$ / $I_L = 2\,mA$ / $I_Z = 23\,mA$ .7.

4 $R_L = \infty$

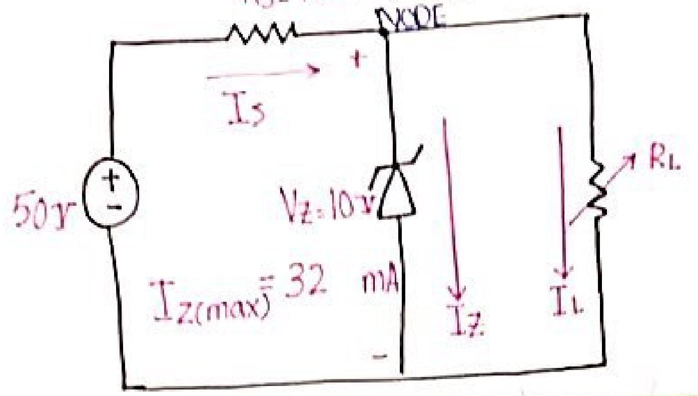
$V_{Th} = 35\,V$.
$I_s = 25\,mA$.
$I_L = 0\,mA$.
$I_Z = 25\,mA$.

* EXAMPLE:- 1) Determine the Range of R_L & I_L that will result V_L being maintained at 10 V ? لا بدو الـ zero يعطينا 10 المباشرة

2) Determine Power rating of Zener Diode?

على الأقل يستحمل الـ Power

* $P = I_Z \cdot R_Z$



SOLUTION:

1- FIND $R_{L(min)}$ that turn Zener Diode ON:-

$$V_L = V_Z = \frac{R_L}{R_L + R_S} \cdot V_i \Rightarrow R_L = \frac{R_S}{V_i - V_Z} \cdot V_Z$$

$$R_{L(min)} = \frac{1K\Omega}{50-10} \cdot 10 = 250\Omega.$$ (ممنوع أقل)

2- $R_{L(max)}$:- KCL Node:-

$I_S = \frac{50-10}{1K\Omega} = 40$ mA (ثابتة)

↙ 32 Zener ↘ 8 $I_{L(min)}$

$$I_{L(min)} = I_S - I_{Zmax}$$

$$R_{Lmax} = \frac{10}{8} = 1.25K\Omega.$$

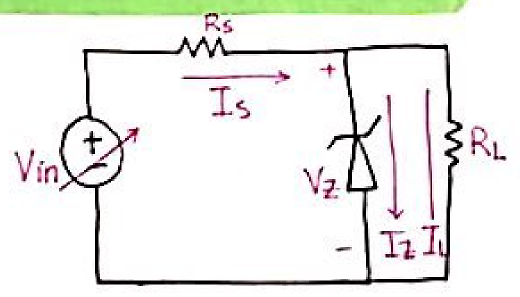
$$250 \leq R_L \leq 1.25K\Omega$$

3- $P_{Z(max)} = V_Z \cdot I_{Zmax} = 10 \cdot 32 = 320$ mW

على الأقل الـ Power تبعه 320 mW

Power rating ≥ 320 mW

* Fixed R_L, Variable V_{in}:-



1- هون بنشوف الـ R_L والـ Vin متغيرة لنوصلها لل min والـ max.

2-

$$V_{th} \geq V_Z$$

$$\frac{R_L}{R_L + R_S} \cdot V_{in} \geq V_Z$$

$$V_{in(min)} \geq \frac{V_Z (R_L + R_S)}{R_L}$$

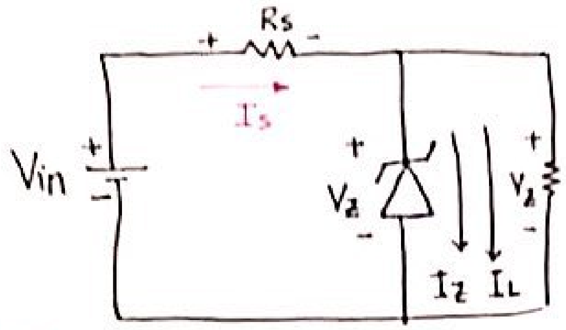
.8.

2 $I_S = I_Z + I_L$

$I_{S(max)} = I_{Z(max)} + I_L \rightarrow I_L = \frac{V_L}{R_L} = 20/1200 = 16.67$ mA

.9.

TO FIND $V_{in(max)}$, FIND KVL in LOOP:-



$$V_{in} = I_S R_S + V_Z$$

$$V_{in(max)} = I_{S(max)} \cdot R_S + V_Z$$

$$I_{S(max)} = I_{Z(max)} + I_L$$

*** Notes:-**

$$V_{in} = V_{in(min)} = \frac{R_L + R_S}{R_L} \cdot V_Z$$

$V_{in(max)}$ limited by $I_{Z(max)}$

$$I_S = I_Z + I_L$$

$$I_{S(max)} = I_{Z(max)} + I_L$$

$$V_{i(max)} = I_{S(max)} \cdot R_S + V_Z$$

⇓

$$V_{in(min)} \leq V_{in} \leq V_{in(max)}$$

---

* **EXAMPLE:**

$I_{Z(max)} = 60\,mA.$
$V_Z = 20\,mA.$
$R_S = 220\,\Omega.$
$R_L = 1.2\,K\Omega.$

FIND RANGE to make Zener ON? V_i.

[1] $V_{in(min)} = \frac{1200+220}{1200} \cdot 20 = 23.07\,V.$

[2] $I_S = I_Z + I_L$

$I_{S(max)} = I_{Z(max)} + I_L \rightarrow I_L = \frac{V_L}{R_L} = 20/1200 = 16.67\,mA$

$$I_{s(max)} = 60\,mA + 16.67\,mA = 76.67\,mA.$$

$$V_{i\,(max)} = (76.67) \cdot 220 + 20 = 36.87\,(V)$$

$$23.07 \leq V_{in} \leq 36.87$$

أقل ما يشتغل في region3

زاد عنها التيار بيزيد وبيحرق الـzener

L7: Zener Diodes : PART(1): (11-6-2020)

هاد الصفحة المطلوبة فقط

(Voltage Regulator)

R_s, $I_s = \dfrac{V_{in} - V_Z}{R_s}$, $I_s = I_Z + I_L$

(V_{in} → min / max; I_Z → max / min; I_L → max / min)

واختيارها جزء مهم.

→ Find Range of acceptable R_s in the voltage Regulator.

حكي مجرد ذكر وما راح نتعمق في الحل بهالدرجة.

1) $I_Z = I_S - I_L \geq I_{Z(min)}$

Worst Case: the smallest value of $(I_S - I_L) > I_{Zmin}$

$$I_{S(min)} - I_{L(max)} \geq I_{Zmin}$$

$$\frac{V_{S(min)} - V_Z}{R_S} - I_{L(max)} \geq I_{Z(min)}$$

$$R_S \leq \frac{V_{S(min)} - V_Z}{I_{Z(min)} + I_{L(max)}} \quad \text{(Upper limit)}$$

---

2) $I_Z \leq I_{Z(max)}$

worst case: largest value of $(I_{S(max)} - I_{L(min)}) \leq I_{Z(max)}$

$$\frac{V_{S(max)} - V_Z}{R_S} - I_{L(min)} \leq I_{Z(max)}$$

$$R_S \geq \frac{V_{S(max)} - V_Z}{I_{Z(max)} + I_{L(min)}}$$

* Slides :EXAMPLE: تحويف مباشر

* Variation of Vz (Using Simplified Method):-

$$r_Z = \frac{\Delta V_Z}{\Delta I_Z}$$

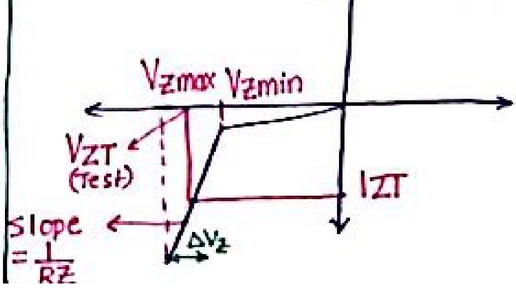
If V_{ZT} & I_{ZT} & r_Z are known

1) $V_{Zmax} = V_{Zm} = V_{ZT} + \Delta I_Z \cdot r_Z$
$= V_{ZT} + (I_{Zmax} - I_{ZT}) \cdot r_Z$

---

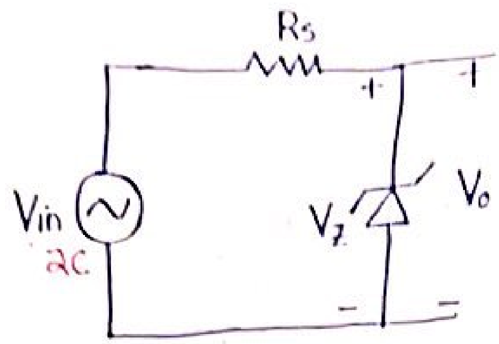
2) $V_{Zmin} = V_{ZK} = V_{ZT} - \Delta I_Z \cdot r_Z$
$= V_{ZT} - (I_{ZT} - I_{Z(min)}) \cdot r_Z$ .1.

* الرسمة في ال Slides :-
+ example



* Clipper Circuits Using Zener Diods:-

ـ ماذا لو كان المصدر هو sinusoidal ويشي Zener Diode



Analysis:- (simplified)

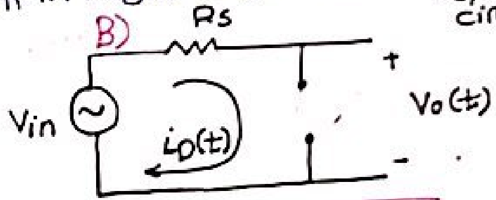
ac voltage → +, −

a) When $V_i(t) < -0.7\,V$ works in region (1) as regulator Diode ON.

$V_{out} = -0.7\,V$

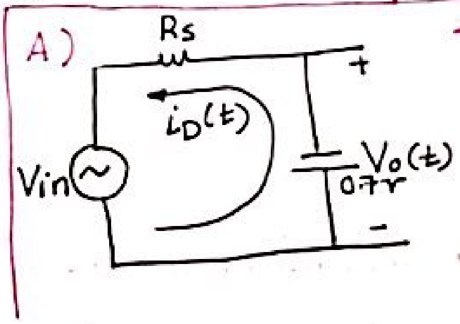
b) When $V_Z > V_i(t) > -0.7\,V$ Zener work in region (2) as diode OFF. "open circuit".

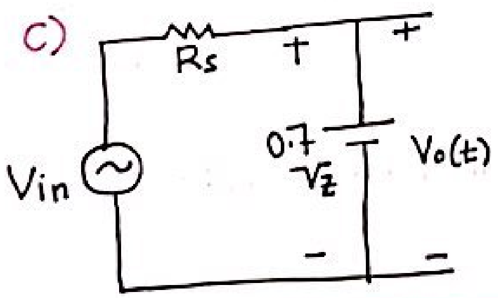
$V_{out} = V_{in}$.



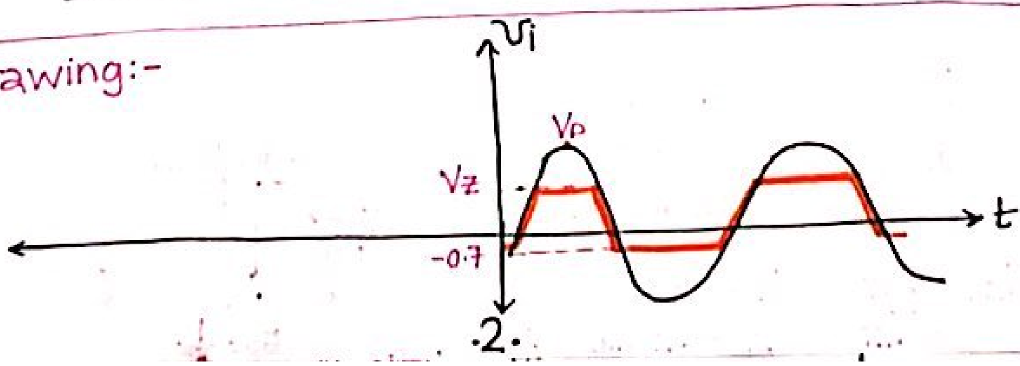
C) When $V_i(t) > V_Z(t)$, Zener work in region (3) as voltag regulator.

$V_o(t) = V_Z$.

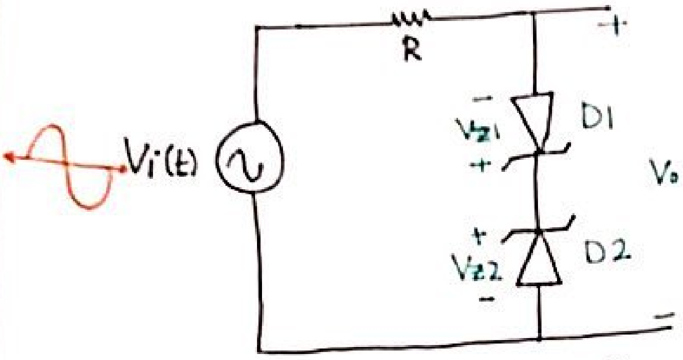




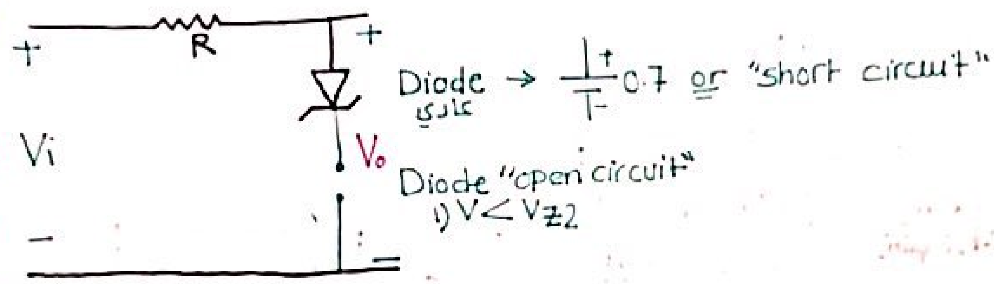
Drawing:-



* Clipper circuits using Zeners:-

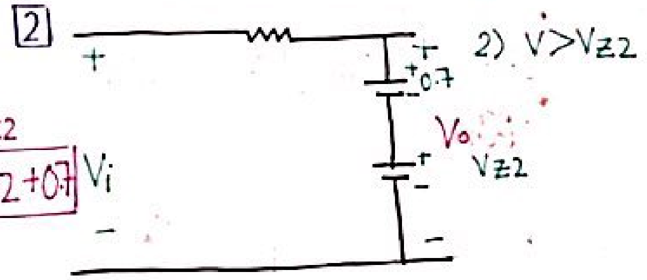


* FIND AND Sketch $V_o(t)$?



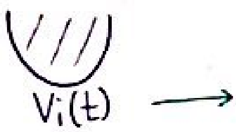
$0.7 < V_i < V_{z2}$

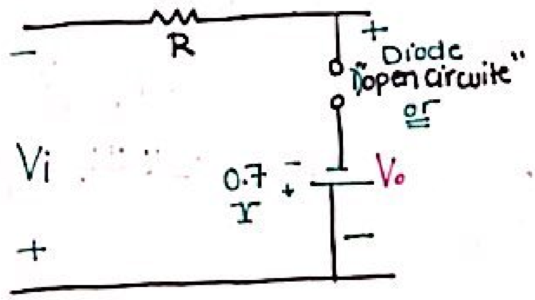
$V_o = V_i$



$V_i > V_{z2}$

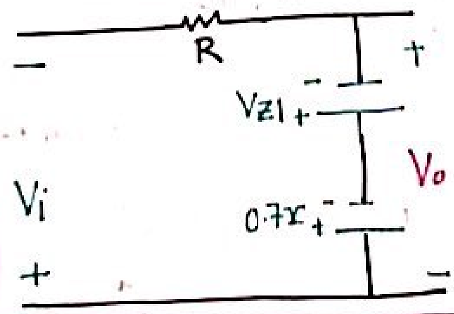
$V_o = V_{z2} + 0.7$





$0.7 < V_i < V_{z1}$

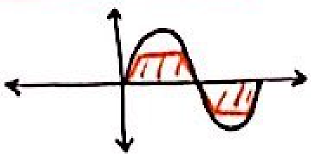
$V_o = V_i$



$V_i > V_{z1}$

$V_o = -(V_{z1} + 0.7)$

Drawing : Clipping Circuit:



* two equivalent Clipper Circuits :-
in slides

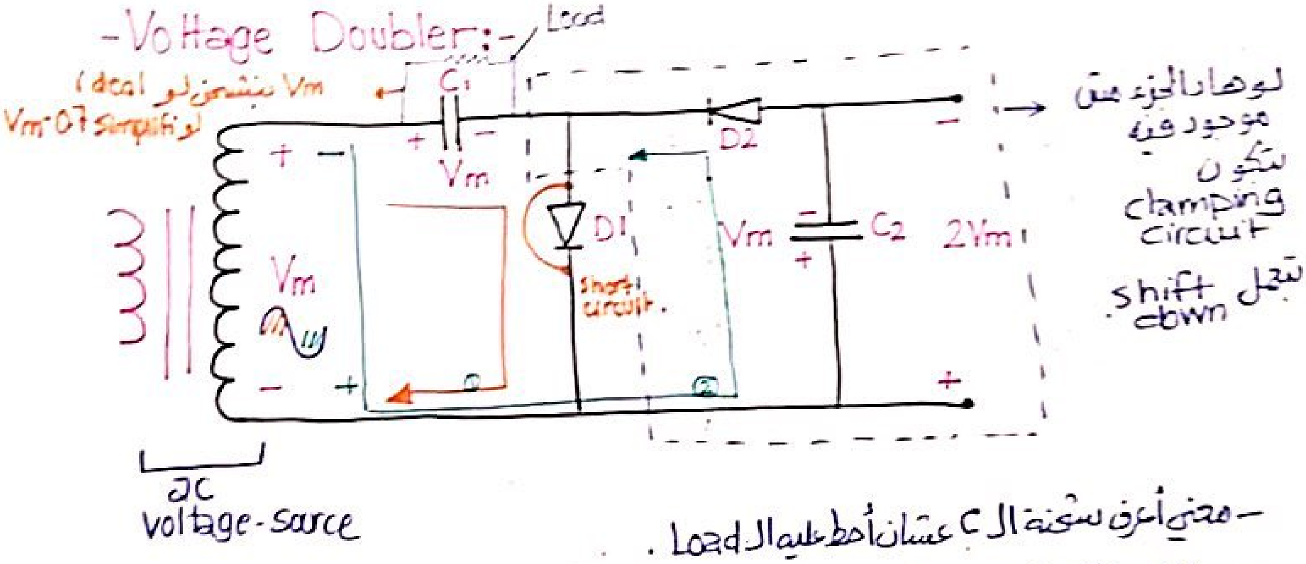
(1)
أوصل أصل استوانوا على دايودين فقط
Zener diodes

(2)
diodes + Battery .

* Voltage - Multiplier Circuits:-

- تكون مصدر فولتية ac ولدي أوصل على dc منه فدي أياه كان الـ Amp لتاعه أكبر من Vp للـ ac .

- Voltage Doubler:-



- معنى أعرف شحنة الـ C عشان أحط عليها الـ Load .
- C1 بنشحن في positive half .
- C2 بنشحن في negative half بالآخر، ويكون الـ C1 مشحون و D2 short circuit فبكون C2 = مصدر Vm + C1 = 2Vm .

* Voltage Tripler and Quardrupler:-

* الرسمة فالـ slides .
- كل section فيها (4) يحتوي على Capacitor والـ Diode .
نطبق على KVL على loop

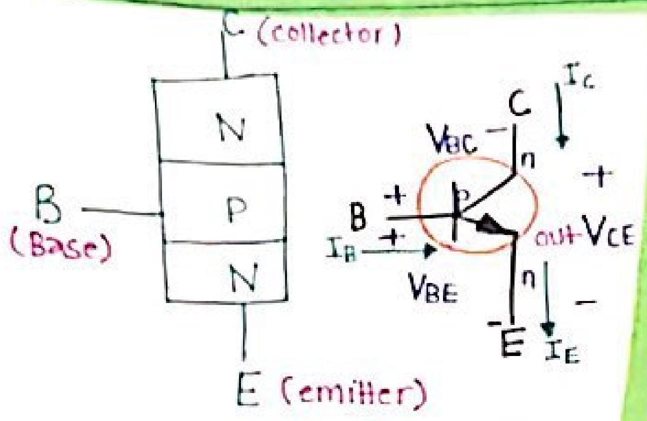
* لـ 3Vm
4Vm
2Vm
هدول على الرسمة ونثبته حسب الـ Polarity .

- C1 راح تنشحن V_M
- C2 " " $2V_M$
- C3 " " 2Vm
- C4 " " 2Vm

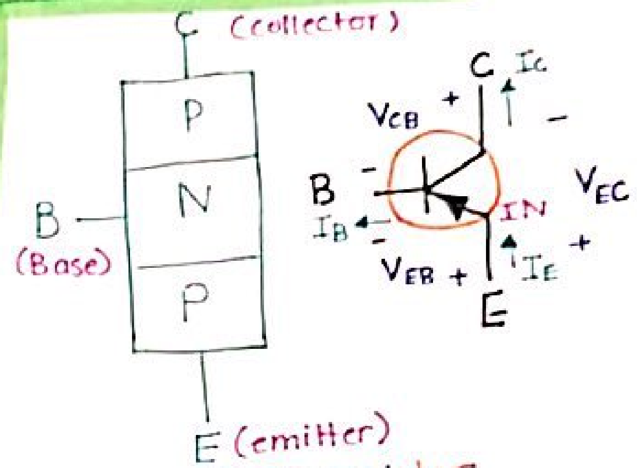
L7: PART(2): Bipolar Junction Transistors:- (BJT):-

- من أهم الـ devices إحدى الـ semi-conductor ، أهم استخدام إله بالـ amplifiers ، وهو مكون أساسي لأي electronics circuit ، والـ 3 terminals . مهمة للـ IC circuits ، وهو مكون أساسي Logic gates .

npn / pnp > 2TYPES ، Base / Emitter / collector > 3 terminals



NPN - Transistor



PNP - Transistor

[1] 2 P-N JUNCTION (2 diodes)
between B → C
B → E

[2] 3 Currents . بأحلاهم الراجعية لنشتغل الـ Transistor كـ amplifier .

* التيارات هي حركة للشحنات الموجبة في الـ device .

* 2-PN JUNCTIONS:-

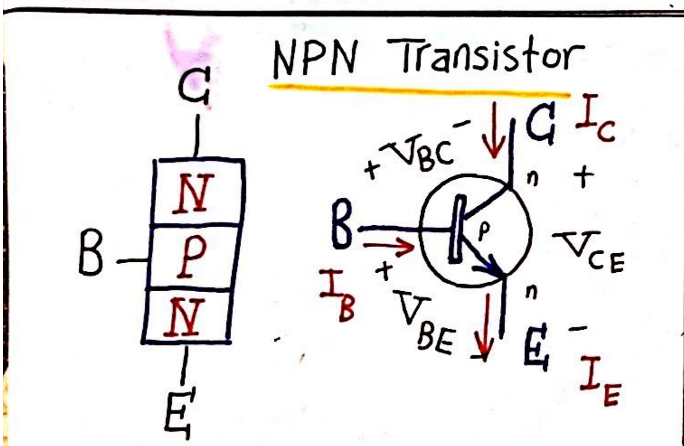
	BE	BC	Mode	
Amplifire	Forward ON	Reverse OFF	VCE defined by circuit LINEAR/active	تشتغل amplifier
switch	ON	ON	$V_{CE(sat)} = \sim 0.2V \approx 0$ / $I_C = I_{C(sat)}$ (أقصى قيمة) staturation C —o—o— E	close switch between C&E
switch	OFF	OFF	VCE defined by Circuit / $I_C = I_b = 0$ Cut-OFF C —o o— E	open switch between C&E
ما راح نحكي عنها	~~OFF~~	~~ON~~	~~inverse Mode~~	

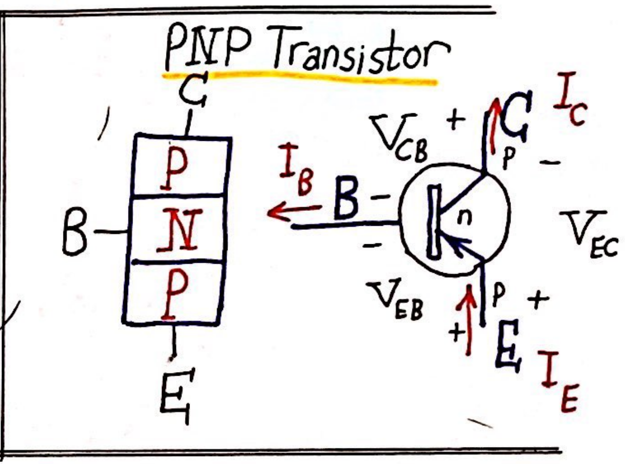
- هدفنا نعمل analysis.

Electronics : ENEE236 : L7 → BJT introduction

« Bipolar Junction Transistor »

- BJT has three terminal device : Base, Emitter, & collector.
- There are two types of BJT :
  - npn type **
  - pnp type



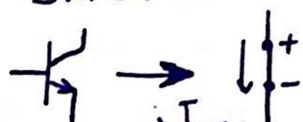
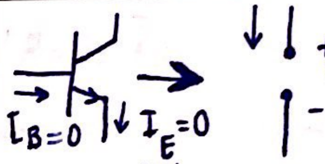


	BE	BC	Mode
Amplifier	ON	OFF	Linear/active
Switch	ON	ON	Saturation/SC (C –o–o– E)
Switch	OFF	OFF	Cut-off (C –o/ o– E)
×	OFF	ON	Inverse mode ×

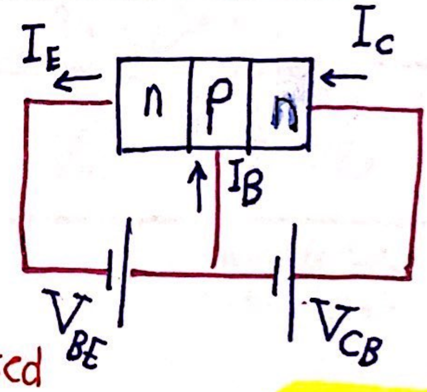
ON ≡ Forward
OFF ≡ Reverse

Junction/Mode	BE	BC	Remarks
Saturation Mode	Fw	Fw	Equi to SC / $I_C = I_C(sat)$, $V_{ce} = V_{ce}(Sat) \cong 0.2\,V$
Active mode (Linear Region)	Fw	Rev	I_c proportional to I_b, V_{ce} defined by Circuit
Cut-off mode	Rev	Rev	Equivalent to OC / $I_b = I_c = 0$, V_{ce} def. by Circuit

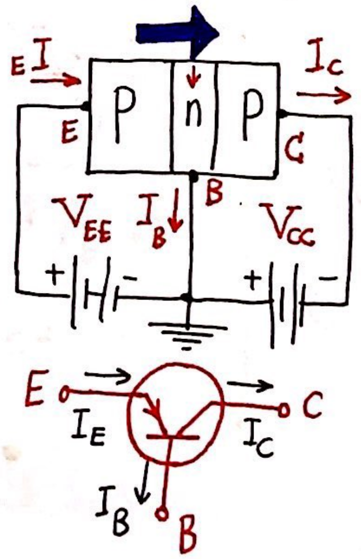
Electronics : ENEE236 : L8 → BJT basics

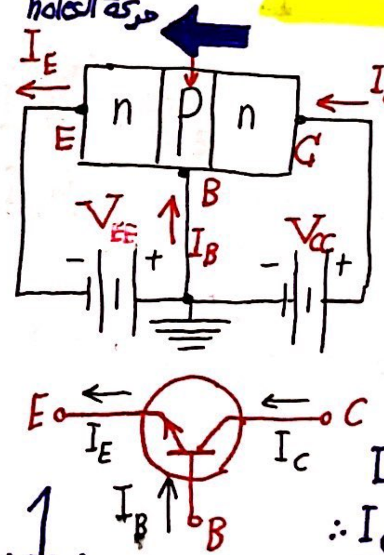
BE	BC	Mode	Remarks V_{CE}
FB	RB	Linear Active	Amplifier $V_{BE} = 0.7$ $I_C = \beta I_B$ $I_E = I_C + I_B \Rightarrow (\beta+1) I_B$ $V_{CE} > V_{CE(SAT)} \cong 0.2V$ (npn)
ON	ON	Saturation	Switch ON $I_{CE(SAT)} = \frac{V_{CC}-0.2}{R_C}$  (sat) I_{CE} V_{CE}(SAt) (0-200)V
OFF	OFF	Cut-off	 $I_B=0$ $I_E=0$ V_{CE} switch off

In active Region



- ✓ Base region is thin & lightly doped
- ✓ The base emitter Jun is fw Biased thus the depletion region at this Jun is reduced "I wrote them previously"





⇒ Active ⇐

اصغر من 1 ; مهمل

$I_C = \alpha I_E + I_{CBO}$

$I_E = I_C + I_B$

$I_C = \alpha(I_C + I_B) + I_{CBO}$

$\therefore I_C = \frac{\alpha}{1-\alpha} I_B + \frac{1}{1-\alpha} I_{CBO}$

Let $\beta = \frac{\alpha}{1-\alpha}$

$\therefore\ I_C = \beta I_B + (\beta+1) I_{CBO}$

$I_C = \beta I_B + I_{CBO}$

If $\alpha = 0.99 \Rightarrow \beta = 99$
If $\alpha = 0.995 \Rightarrow \beta = 199$] $\beta = \frac{\alpha}{1-\alpha}$

الخلاصة ⇒ In active Region:

$I_C = \alpha I_E + I_{CBO}$

$I_C = \beta I_B + (\beta+1) I_{CBO}$

$I_C = \beta I_B + I_{CBO}$

$I_E = I_B + I_C$

Approximate relationships:

$I_C \cong \alpha I_E \cong I_E$

$I_C \cong \beta I_B \quad // \beta = \frac{\alpha}{1-\alpha}$

$I_E \cong (\beta+1) I_B$

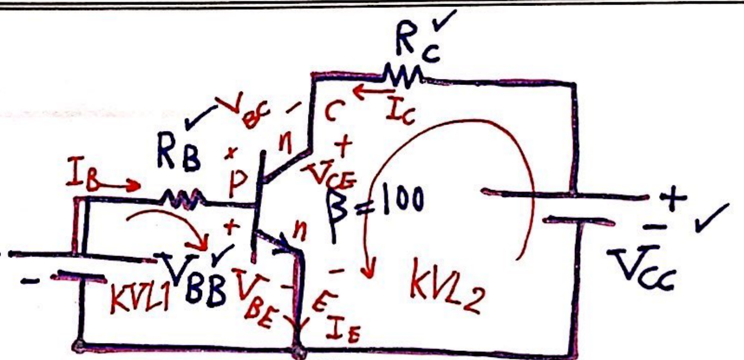
Example: Analysis DC

Voltage, Current, Power

$I_B, I_C, I_E, V_{BE}, V_{BC}, V_{CE}$

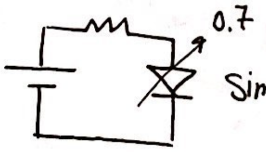
لو V_{BE} f.B ⇐ كان يحكي انها = $V0.7$

[Amp. Mode]



- ممكن اوخذ loop حوالين الـ Transistor
- " " على كل السيركت من برا

[KVL1] $V_{BB} = I_B R_B + V_{BE}$



Simplified

$I_B = \frac{V_{BB} - 0.7}{R_B}$

$I_C = \beta I_B$ ✓

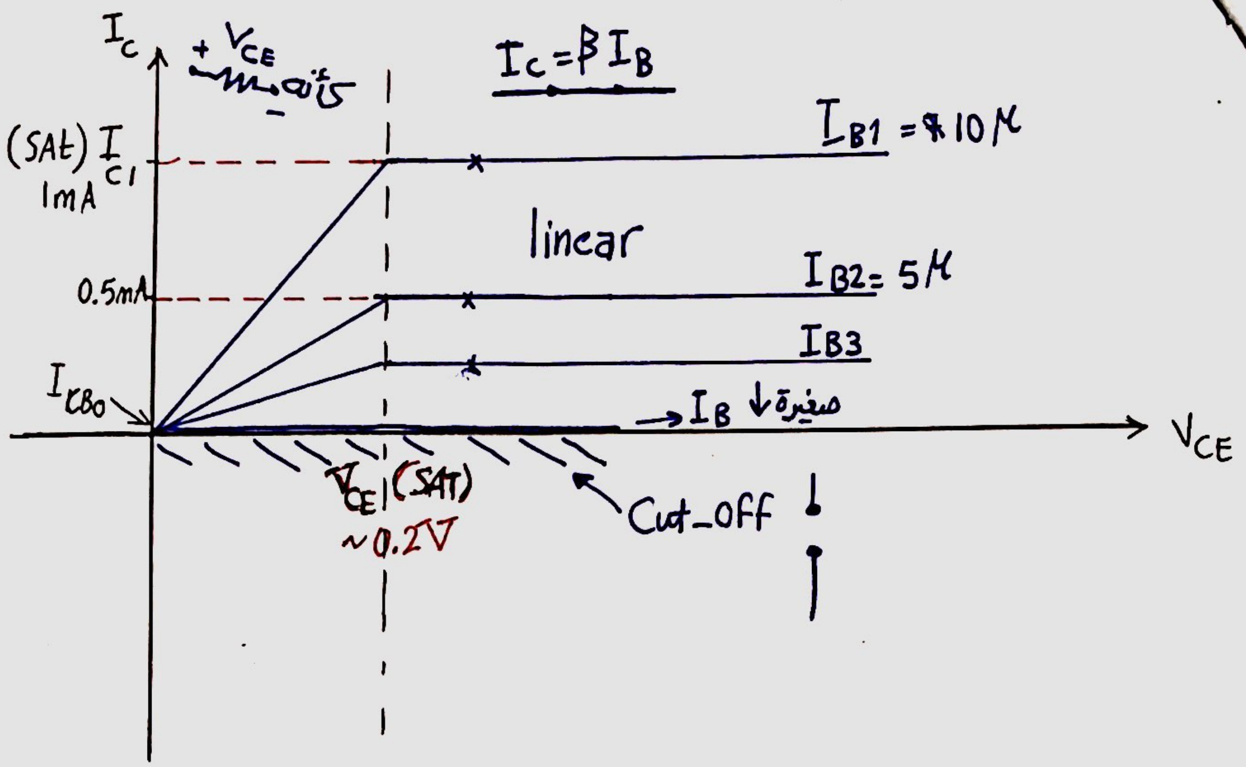
$I_E = I_C + I_B$ ✓

[KVL2] $V_{CC} = I_C R_C + V_{CE}$

$V_{CE} = V_{CC} - I_C R_C$ ✓ "Assume $I_C \uparrow \Rightarrow$ then $V_{CE} \downarrow$"

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

"Assume $I_C \downarrow R_C \Rightarrow V_{CE} \uparrow$ / if $I_C = 0 \Rightarrow V_{CE} = V_{CC} \Rightarrow$ O.C



1. In the Cutoff region:

$$I_B = I_C = I_E = 0$$

2. In the active region:

$$I_C = \alpha I_E$$

$$I_C = \beta I_B$$

$$I_E = (\beta + 1) I_B$$

$V_{BE} = 0.7\,v$, Si, npn

$V_{BE} = -0.7\,v$, Si, pnp

$V_{CE} > V_{CE,sat} = 0.2V$, Si, npn

$V_{CE} < V_{CE,sat} = -0.2V$, Si, PnP

بنفحص V_{BC} اذا طلع سالب معناة
معناة Jun.off ⇐ linear mode

3. In the Saturation region:

$$V_{CE} = V_{CE,sat}$$

Electronics : ENEE236 : L9 : Part 1 → BJT modes of operation

Example: Find mode of operation & the Q point V_{CEQ}, I_{CQ}

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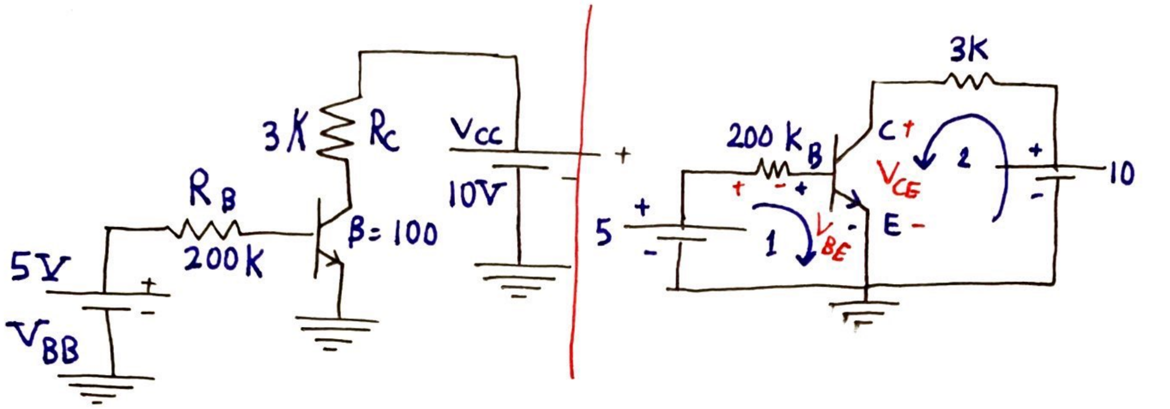


BE Junction ⇒ FW Biased (ON) → linear
→ Saturation

Assume BJT in Active mode.

$5 = I_B 200k + V_{BE}$ (0.7) "Loop 1"

$I_B = \frac{5 - 0.7}{200k} = 0.0215\ mA$. / $I_E = (\beta+1) I_B = 101 \cdot (0.0215\ mA) =$

$I_C = \beta I_B = 100 \cdot 0.0215\ mA = 2.15\ mA$ or $I_E = 2.1715\ mA$

$10 = 3I_C k + V_{CE}$ "Loop 2"

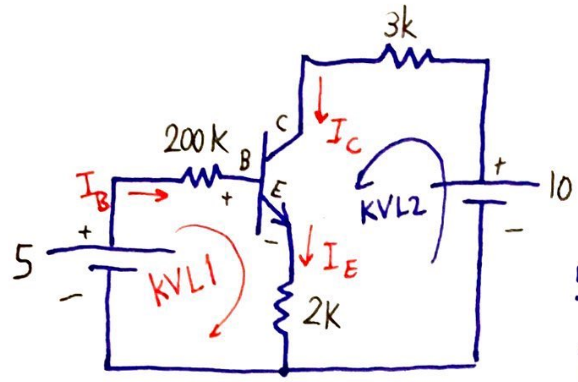
$V_{CE} = 10 - 3k(2.15m)$

$= 10 - 3(2.15) = 3.55 > 0.2$ linear BJT

$I_{CQ} = 2.15\ mA$

$V_{CEQ} = 3.55\ V$

Example: Find mode of operation & the Q-Point V_{CEQ}, I_{CQ}



$I_E = (\beta+1) I_B$

Assume Active mode:

KVL1: $5 = I_B 200k + V_{BE} + 2k I_E$ (V_{BE} → 0.7)

$5 = I_B 200k + 0.7 + I_E 2k$ (I_E → $(\beta+1) I_B$)

$$I_B = \frac{5-0.7}{200k + (\beta+1).2k} = 10.7\,\mu A$$

(β → 100)

$I_C = \beta I_B = 100.(10.7\,\mu) = 1.07\ mA$

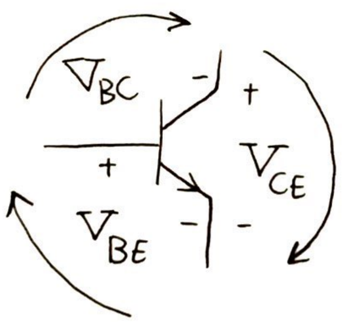
$I_E = I_C + I_B = 1.0807\ mA$

KVL2: $10 = 3k I_C + V_{CE} + 2k I_E$

$V_{CE} = 10 - 3k(1.07m) - 2k(1.0807m)$

$= 10 - 3.21 - 2.1614 = 4.6286\ V > 0.2$ → Our Assumption is Correct

V_{BC}?



$V_{BE} = V_{BC} + V_{CE}$

$0.7 = V_{BC} + 4.6286$

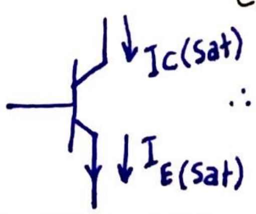
$V_{BC} = -3.93 < 0$ BC Junc. is off

* Confarmes that BJT in active mode *

Method 2: Stauration ⇒ $V_{CE} = V_{CE(SAT)} \cong 0.2V$

Assumption is wrong

$V_{CC} = I_{C(SAT)} \cdot 3k + I_{E(SAT)} 2k + V_{CE(SAT)}$

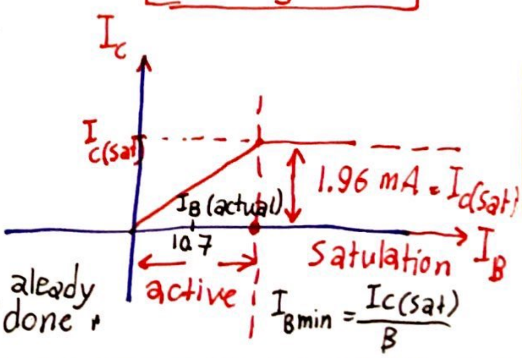


$$\therefore I_{C(sat)} \cong \frac{10-0.2}{5k} = 1.96\ mA$$

$$I_{B(min)} = \frac{1.96\ m}{100} = 19.6\ mA$$

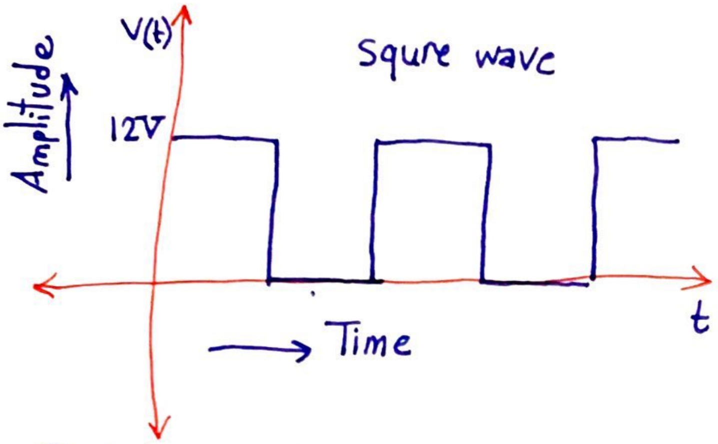
باكل السابق انا طلعت I_B وطلعت = 10.7 يعني اقل من min
وهذا يعني انه بالـ active mode

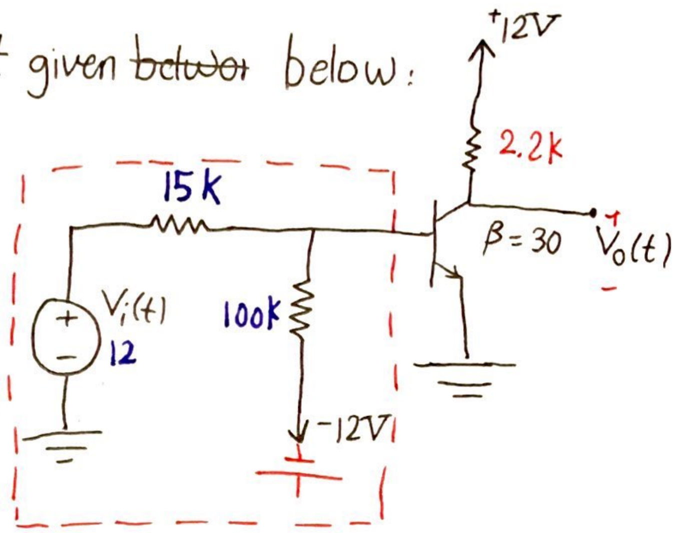
.2. ⇐ KVL already done



BJT as switch :

Example : Find $V_o(t)$ for the Input given ~~below~~ below:

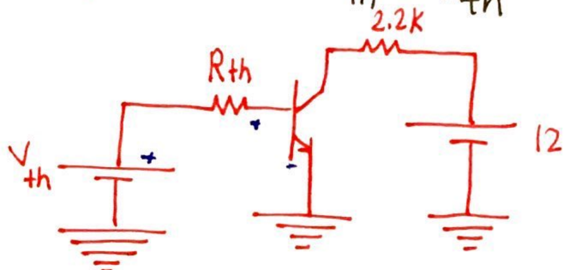




Solution: Let $V_i(t) = 12$ volt ⟹ Caculate V_{th} & R_{th}

$R_{th} = 15K // 100K = 13K$

$V_{th} = V_{OC} = 8.9\ V$



Since base emitter junc. is fw bias ⟹ active / saturation

▷ Assume that the tras. in the Saturation Region

$$I_C = I_{C,sat} = \frac{V_{CC} - V_{CE(sat)}}{R_C} = \frac{12 - 0.2}{2.2k} = 5.36\ mA$$

$$I_{B(min)} = \frac{I_{C,sat}}{\beta} = \frac{5.36\ mA}{30} = 0.18\ mA$$

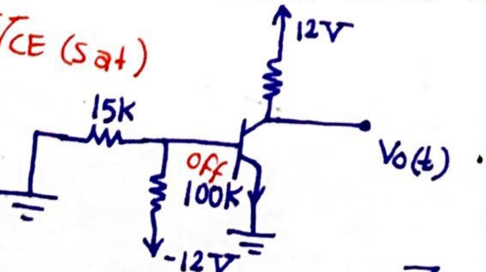
$$I_B = \frac{V_{th} - V_{BE}}{R_{th}} = \frac{8.9 - 0.8}{13\ k} = 0.62\ mA$$

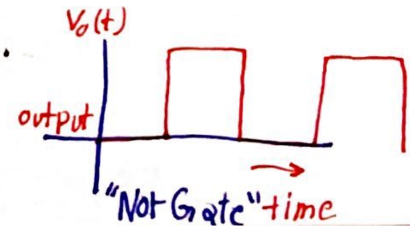
Since $I_B > I_{B(min)}$ the transistor is in the saturation mode

output voltage = $V_{CE\ (sat)}$

∴ Let $V_i(t) = 0$ Volt

$V_o = V_{CC}$





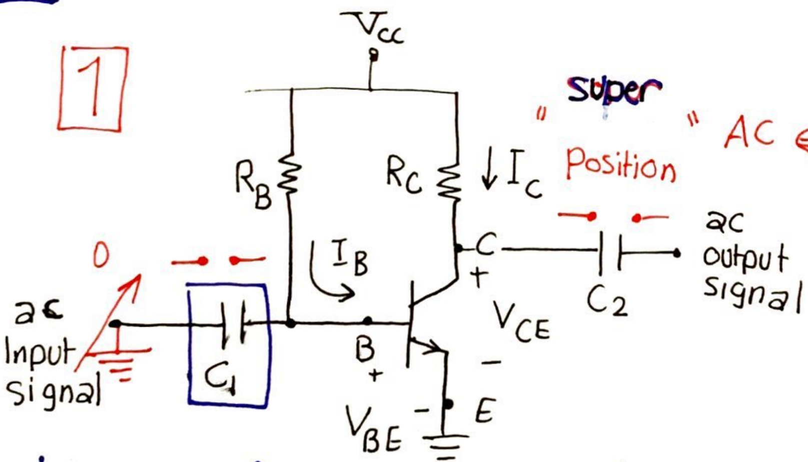
Electronics : ENEE236 : L9 : Part 2 → BJT Biasing

L8 - DC Biasing - BJTs

Putting External DC Sources that will forse the transistor to work in one of the modes.

1. Fixed-bias Circuit.
2. Emitter-Stabilized bias Circuit.
3. DC bias with voltage feedback
4. Voltage divider bias Circuit.

1

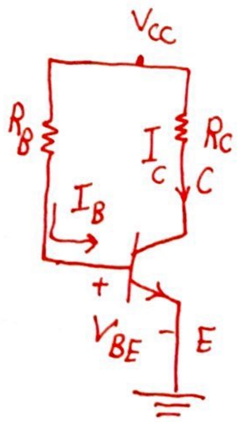


AC ⇐ kill احنا معنيين بال DC فبنقتل

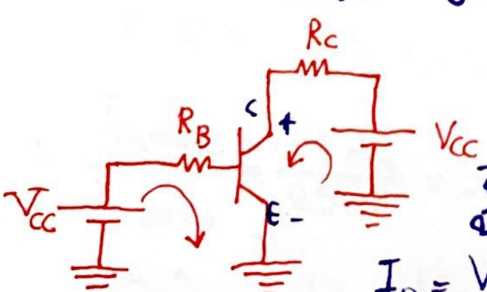
Impenence for Capacitor ⇒ $\frac{1}{j\omega_c}$

Dc equ. circuit ⇒ means $f = 0$

$$X_c = \frac{1}{2\pi f c} \cong \frac{1}{j\omega_c} \cong \infty$$ "open circuit" ⇒



Fixed bias



المكافئة من السابقة

$$I_B = \frac{V_{CC} - V_{BE}}{R_c} \quad , \quad I_C = \beta I_B \quad , \quad V_{CE} = V_{CC} - I_C R_C$$

$\beta \Rightarrow (20-200)$ data sheet

$V_{CE} = V_C - V_E$

Since $V_E = 0 \Rightarrow V_{CE} = V_C$

$\therefore V_{CE} = V_{CC} - I_C R_C$ & $V_{BE} = V_B - V_E$

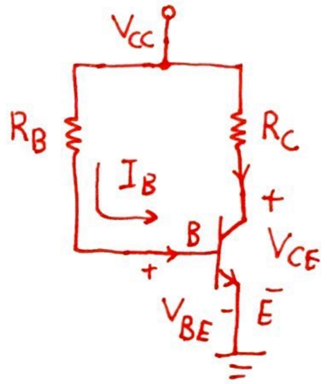
$\therefore V_{BE} = V_B$

Design of fixed Biased Circuit

Assume $V_{CC} = 10V$, $\beta_{nominal} = 100$, $\beta_{min} = 50$, $\beta_{max} = 150$

Design for Q-point : $V_{CEQ} = 5V$, $I_{CQ} = 1mA$ (find unknown Comp. values R_B & R_C

$$I_{BQ} = \frac{I_{CQ}}{\beta_{nominal}} = \frac{1mA}{100} = 10\mu A$$



$$I_B = \frac{V_{CC} - V_{BE}}{R_B} \Rightarrow$$

$$R_B = \frac{V_{CC} - V_{BE}}{I_B} = \frac{10 - 0.7}{10\mu A} = 930\,k\Omega$$

$V_{CE} = V_{CC} - I_C R_C$

$V_{CEQ} = 5 = 10 - I_C R_C$

$$\therefore R_C = \frac{5}{1mA} = 5k\Omega$$

I_B : ما بتأثر ⇐ اذا تغيرت قيمة β

$I_C = \beta I_B$: بتأثر

If $\beta = \beta_{min} = 50 \Rightarrow I_B = 10\mu A$

$I_C = \beta I_B = (50)(10\mu) = 0.5\,mA$

$V_{CE} = V_{CC} - I_C R_C$

$= 10 - (0.5mA)(5k\Omega) = 7.5V$

If $\beta = \beta_{max} = 150 \Rightarrow I_B = 10\mu A$

$I_C = \beta I_B = (150)(10) = 1.5\,mA$

$V_{CE} = V_{CC} - I_C R_C$

$= 10 - (1.5mA)(5k\Omega) = 2.5V$

for $50 \leq \beta \leq 150$ ⇐

$I_B = 10\mu A$ fixed

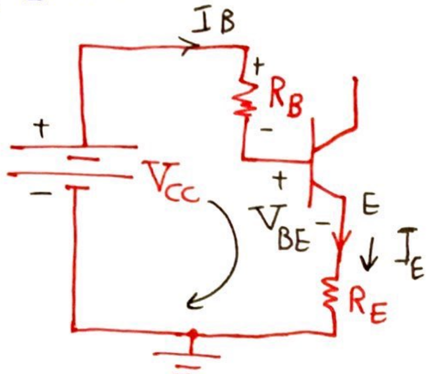
$0.5mA \leq I_C \leq 1.5mA$

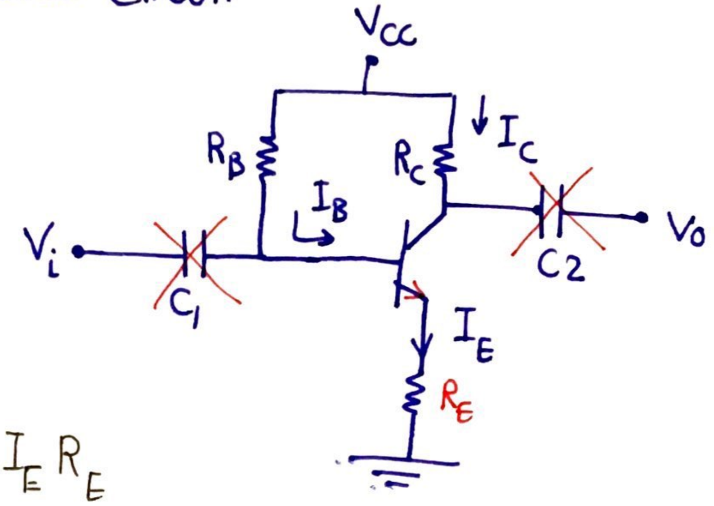
$7.5V \geq V_{CE} \geq 2.5V$

$$\therefore \frac{I_{C(max)}}{I_{C(min)}} = \frac{1.5mA}{0.5mA} = 3$$

مقياس اداء "مش ثابت"

2 Emitter-Stabilized Bias Circuit





$$V_{CC} = I_B R_B + V_{BE} + I_E R_E$$

$$I_E = (\beta+1) I_B$$

$$V_{CC} = I_B R_B + V_{BE} + (\beta+1) I_B R_E \Rightarrow I_B(R_B + R_E) + V_{BE} = V_{CC}$$

($R_E \to (\beta+1)$)

$$I_B = \frac{V_{CC} - V_{BE}}{R_B + (\beta+1) R_E} \Rightarrow \downarrow I_B \Leftarrow \uparrow \beta \text{ اذا}$$

$$I_E = \frac{V_{CC} - V_{BE}}{\frac{R_B}{\beta+1} + R_E} \Rightarrow$$

I_E بتعتمد على β

In order to get I_E almost indep. of β we choose:

$$R_E \gg \frac{R_B}{\beta+1}$$

$$I_E \cong \frac{V_{CC} - V_{BE}}{R_E}$$

Also, in order to guarantee operation in Linear mode we choose

$$0.1 V_{CC} \leq V_E \leq 0.2 V_{CC}$$

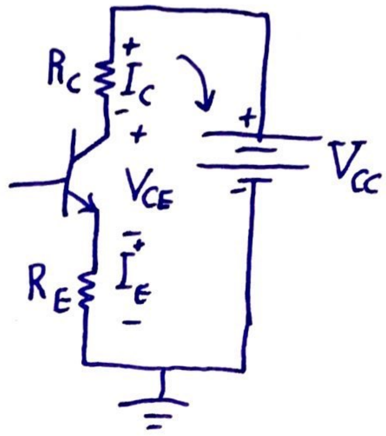
$$I_E R_E + V_{CE} + I_C R_C - V_{CC} = 0$$

$(I_E \cong I_C)$ $$V_{CE} = V_{CC} - I_C (R_C + R_E)$$

Also; $V_E = I_E R_E$

$$V_C = V_{CE} + V_E = V_{CC} - I_C R_C$$

$$V_B = V_{CC} - I_R R_B = V_{BE} + V_E$$



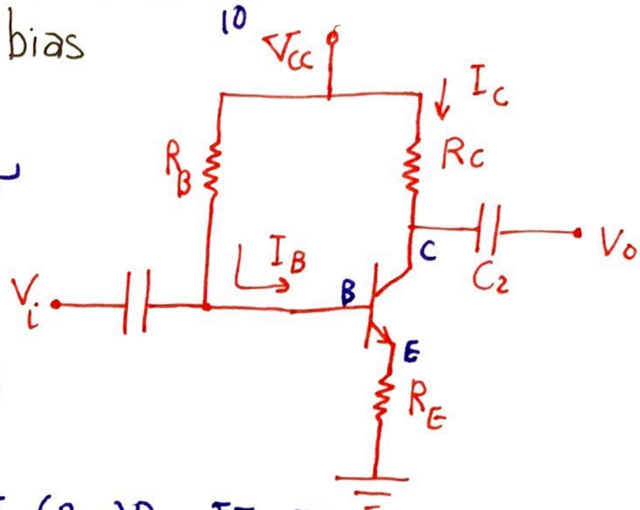
Design: Emitter Stabilization bias

نفس المعطيات السابقة

Let $V_E = 0.1\, V_{CC}$ $\Rightarrow$ بس في حال V_E مش معروفة

$$V_E = \frac{1}{10} \cdot 10 = 1\ V$$

$$I_E = \frac{V_E}{R_E} \Rightarrow R_E = \frac{1}{1.01\ mA} \cong 1k\Omega$$



$$I_B = \frac{V_{CC} - V_{BE}}{R_B + (\beta+1) R_E} \Longrightarrow R_B I_B + I_B(\beta+1) R_E = V_{CC} - V_{BE}$$

$$R_B = \frac{V_{CC} - V_{BE} - I_B(\beta+1) R_E}{I_B}$$

$$= \frac{10 - 0.7 - 10\mu A (100+1)\, 1k}{10\ \mu A}$$

$$V_{CE} = V_{CC} - I_C R_C - V_E$$

$$V_{CEQ} = 5 = 10 - 1 - I_C R_C$$

$$\therefore R_C = \frac{4}{1mA} = 4k\Omega$$

[هسا نتحقق من β] شو تأثيرها

If $\beta = \beta_{min} = 50 \Rightarrow I_B = \frac{9.3}{829k\Omega + 51k\Omega} = 10.56\mu A$

$I_C = \beta I_B = (50)(10.56\mu) = 0.528\,mA$

$V_{CE} = V_{CC} - I_C R_C - V_E$

$V_{CEQ} = 10 - (0.528mA)(4k\Omega) - 1 = 6.89\ V$

If $\beta = \beta_{max} = 150 \Rightarrow I_B = \frac{9.3}{829k + 151k} = 9.489\mu A$

$I_C = \beta I_B = (150)(9.489\mu) = 1.423\,mA$

$V_{CE} = V_{CC} - I_C R_C - V_E$

$V_{CEQ} = 10 - (1.423mA)(4k\Omega) - 1 = 3.31\ V$

$$50 \le \beta \le 150$$

$$10.56\mu \ge I_B \ge 9.489\mu$$

$$0.528 \le I_C \le 1.423$$

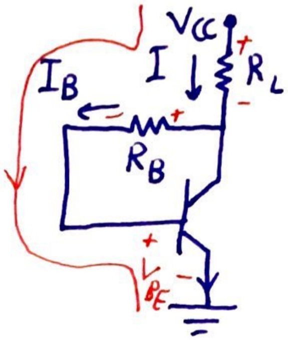
$$6.89 \ge V_{CE} \ge 3.31$$

$$\therefore \frac{I_{C\,max}}{I_{C\,min}} = \frac{1.423\,mA}{0.528\,mA} \cong 2.7$$

Improved

مش ثابت لسا بس افضل

3 Base_Emitter Loop



$$V_{CC} - IR_L - I_B R_B - V_{BE} = 0$$

$$I = I_C + I_B$$

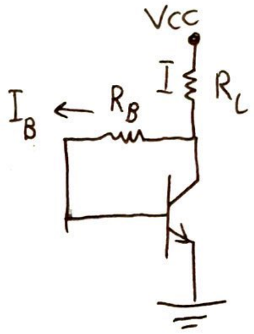
$$I_C = \beta I_B \Rightarrow I_B = \frac{V_{CC} - V_{BE}}{R_L(\beta+1) + R_B}$$

$$V_{CC} = IR_L + V_{CE} \quad \dots (*)$$

$$I = I_C + I_B$$

$$V_{CE} = V_{CC} - (I_C + I_B) R_L$$

∴ Design : Voltage feed back bias



$V_{CC} = 10V$, $\beta_{nominal} = 100$ ⇐: نفس المطاليب

$\beta_{min} = 50$, $\beta_{max} = 150$, Design for $V_{CEQ} = 5V$

$V_{CQ} = 1mA$

$$R_L = \frac{V_{CC} - V_{CE}}{I_C + I_B} \ (\text{as } *) = \frac{10 - 5}{1mA + \frac{1mA}{100}} \simeq 4.95\,k\Omega$$

$$I_B = \frac{V_{CC} - V_{BE}}{R_L(\beta+1) + R_B} \Rightarrow R_B = 430\,k\Omega$$

If $\beta = \beta_{min} = 50$

$I_B = 0.013627\ mA$

$I_C = 0.68\ mA$

If $\beta = \beta_{max} = 150$

$I_B = 0.00793\ mA$

$I_C = 1.19\ mA$

for

$$50 \leqslant \beta \leqslant 150$$

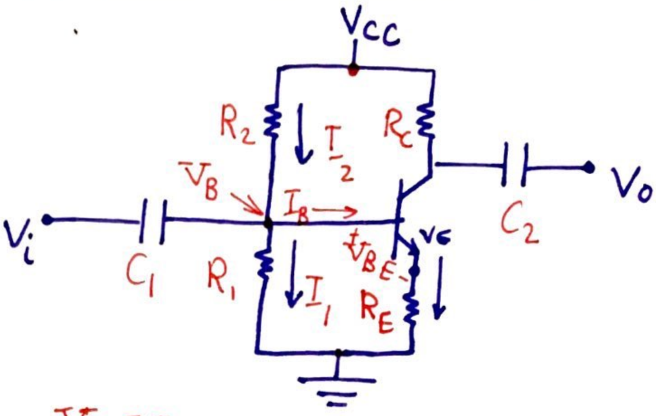
$$0.68\ mA \leqslant I_C \leqslant 1.19\ mA$$

$$\therefore \frac{I_{Cmax}}{I_{Cmin}} = \frac{1.19\ mA}{0.68\ mA} \simeq 1.75$$

Improved but not stable

Electronics : ENEE236 : L10 → BJT: Baising (L8)

4 Voltage Divider Bias



$I_2 = I_1 + I_B$; $I_1 \gg I_B$

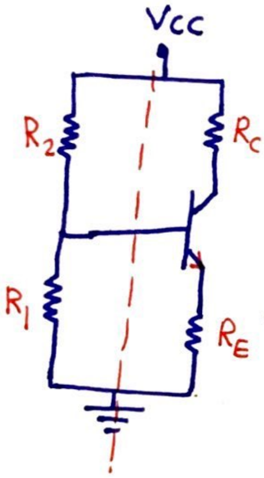
$I_2 \cong I_1$

$$V_B = \frac{R_1}{R_1 + R_2} V_{CC}$$

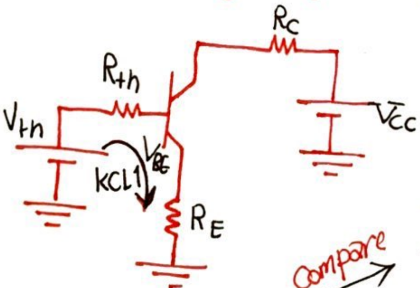
$V_B - V_{BE} - V_E = 0 \Rightarrow V_E = V_B - V_{BE}$

$$I_{E(approximate)} = \frac{V_E}{R_E} = \frac{V_B - V_{BE}}{R_E}$$ ⇒ Independent of β "مابتعتمد"

Same



Exact analysis :



$R_{th} = R_1 // R_2$

$$V_{th} = \frac{R_1}{R_1 + R_2} \cdot V_{CC}$$

compare

$$I_{E(exact)} = \frac{V_{th} - V_{BE}}{R_E + \frac{R_{th}}{\beta + 1}}$$ → مانبعرا عليه صفر

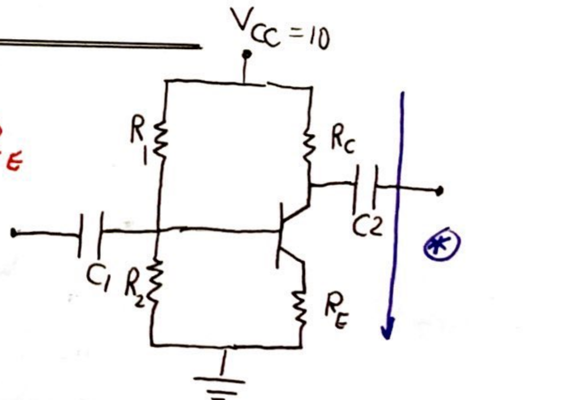
اذا بنلاحظ ⇒ $$I_{E(approximate)} = \frac{V_B - V_{BE}}{R_E}$$ حسب المعادلات $V_B \equiv V_{th}$ بدنا نلاحظ انو وجاي R_E اكبر بكثير

$\therefore$ Make $R_E \gg \frac{R_{th}}{\beta + 1}$

* $R_{th} \ll \frac{(\beta + 1) R_E}{10}$ *

$R_{th} \ll \frac{\beta R_E}{10}$

$V_{CEQ} = 5V$, $I_{CQ} = 1mA$



1 let $V_E = 0.1 V_{CC} = 1V$ ⇒ $I_E = \frac{V_E}{R_E} \Rightarrow \frac{V_E}{I_E} = R_E$

$R_E = \frac{1}{1.01m} = 1k\Omega$

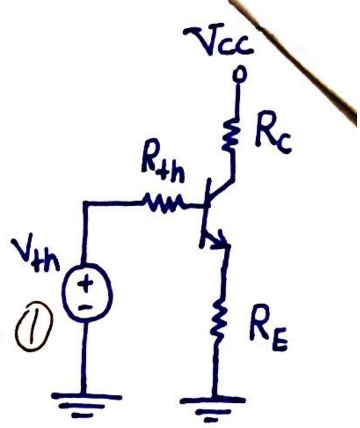
2 let $R_{th} = \frac{R_E \cdot \beta_{nominal}}{50} = \frac{1k \cdot 100}{50} = 2k\Omega$

from (*) 3 $V_{CC} = R_C I_C + I_E R_E + V_{CE}$

$$R_C = \frac{V_{CC} - V_{CE} - V_E}{1mA} = \frac{10 - 5 - 1}{1mA} = 4k\Omega$$

.1.

4 at loop $I_E = \dfrac{V_{th} - V_{BE}}{\dfrac{R_{th}}{\beta+1} + R_E}$



$$V_{th} = \frac{R_1 V_{cc}}{R_1 + R_2} = I_E\left(\frac{R_{th}}{\beta+1} + R_E\right) + V_{BE} = 1.72V \ldots (1)$$

$$R_{th} = R_1 // R_2 = \frac{R_1 R_2}{R_1 + R_2} = 2k\Omega \ldots (2)$$

Sloving (1) & (2) $\Rightarrow R_1 = 2.42\,k\Omega$, $R_2 = 11.64\,k\Omega$

If $\beta = \beta_{min} = 50$
$I_C = 0.982\ mA$

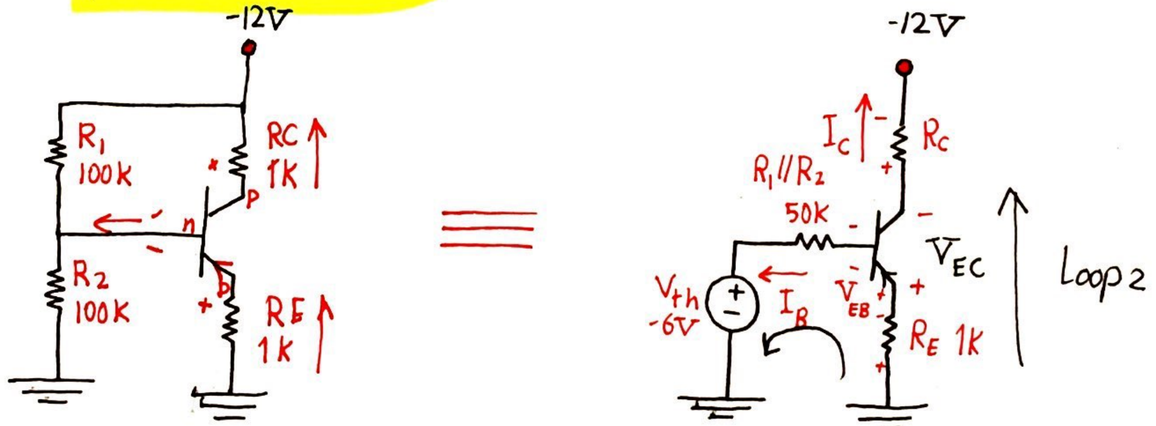
If $\beta = \beta_{max} = 150$
$I_C = 1.0069\ mA$

$50 \leq \beta \leq 150$
$0.982\ mA \leq I_C \leq 1.0069\ mA$

$\therefore \dfrac{I_{C(max)}}{I_{C(min)}} = \dfrac{1.0069}{0.982} \simeq 1.0254$ "the best" very Good Qpoint Stability

---

PNP transistor



$V_{th} + I_B * 50K + V_{EB} + I_E * 1K = 0$
$-6 + I_B * 50K + 0.7 + I_E * 1K = 0$

$\beta = 99$ $I_E = \dfrac{V_E}{R_E}$
$I_E = (\beta+1) I_B \ldots (*)$

from (*) ~~$I_B \simeq I_E$~~ $\Rightarrow I_B = \dfrac{6-0.7}{(50K + 100K)} = 35.3\ uA$ ممنوع سالب

$I_C = 3.49\ mA$

---

from Loop 2 $I_E R_E + V_{EC} + I_C R_C - 12 = 0$
$V_{EC} = 5.02$

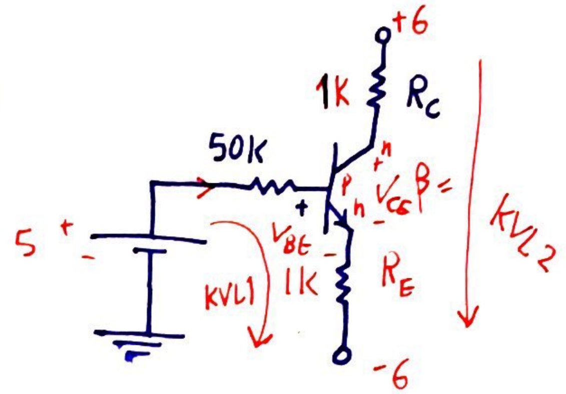
$5 = I_B 50K + V_{BE} + I_E \cdot 1K + (-6)$

$I_E = (\beta + 1) I_B$

$I_B = \dfrac{11 - 0.7}{50K + 100K} = \checkmark$

$V_{CE} \Rightarrow$ KVL2

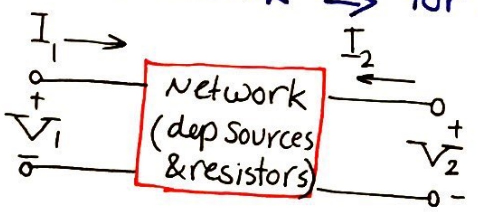
$6 + 6 = I_C R_C + V_{CE} + I_E R_E$



⟪L9⟫ BJT AC Analysis

- re model ✗
- Hybrid equivalent model. ✓

⇒ Two-port Network ⇒ for analysis (6) عدهم



Note: this page is for Information only

[1] Development of the h-parameter model of BJT:

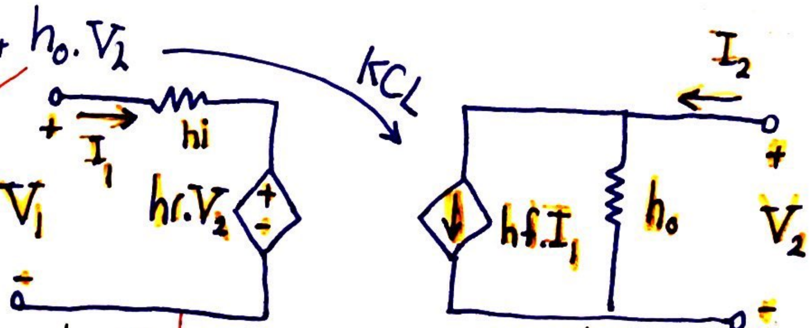
h-Parameter equation:

$V_1 = h_i \cdot I_1 + h_r \cdot V_2$

$I_2 = h_f I_1 + h_o \cdot V_2$

بس ال h-paramet. اللي مطلوب

h_i: Ω; h_r, h_f: مالها وحدة قياس, Unitless; h_o: Ω^{-1}



$h_i = \left.\dfrac{V_1}{I_1}\right|_{V_2=0}$

$h_f = \left.\dfrac{I_2}{I_1}\right|_{V_2=0}$

with $V_2 = 0$ (Short)

$h_r = \left.\dfrac{V_1}{V_2}\right|_{I_1=0}$

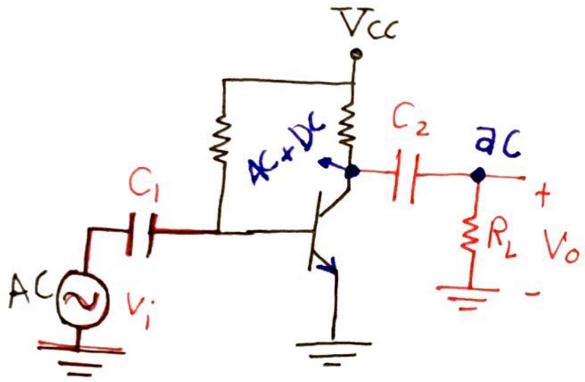
$h_o = \left.\dfrac{I_2}{V_2}\right|_{I_1=0}$

with $I_1 = 0$ (open)

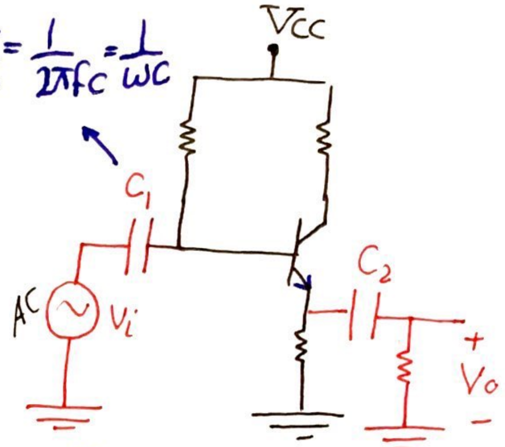
back ⇒

(L9) BJT Configurations

- Common Emitter
- Common Base
- Common Collector



$X_C = \frac{1}{2\pi f c} = \frac{1}{\omega c}$



Common Emitter

- ac Input Base Side
- as Output Collector side

Common Collector

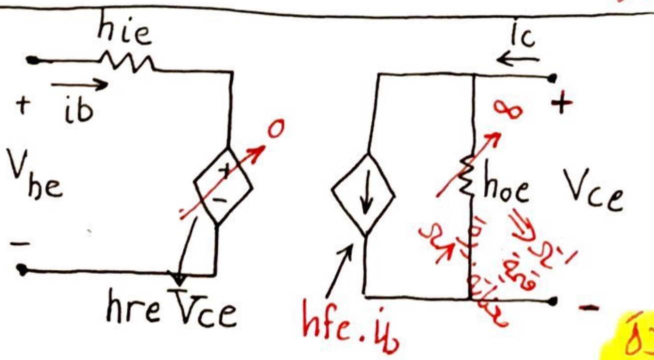
- as Input Base Side
- ac Output Emitter Side

$$X_c = \frac{1}{\omega c}$$

dc → $f = 0$ → $X_c = \infty$ "open"

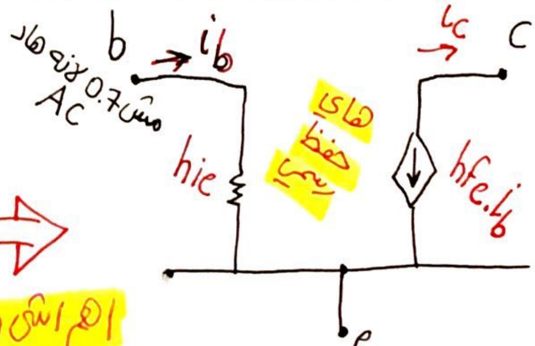
ac → $f\uparrow\uparrow$ → $X_c \cong 0$ "Short"

Use same h-parameters



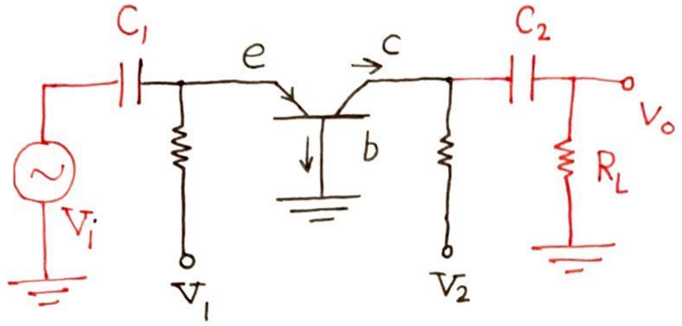
Detailed eq. circuit

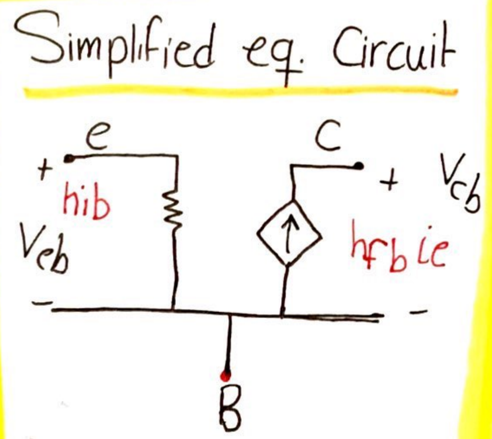
اهم اشي بالمادة



Simplified eq. circuit

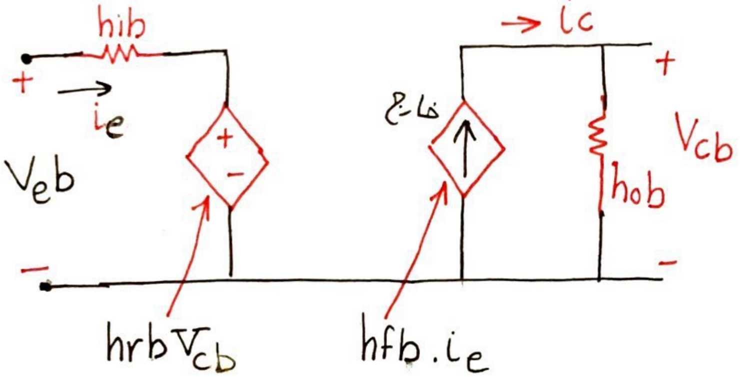
Common Base





ac input → Emitter

ac Output → Collecter



? [hie , hib , hfe , hfb] ⇒ $\frac{i_c}{i_e} = \alpha = \frac{\beta}{\beta+1}$

hie ⇓ $\frac{V_T}{I_{BQ}}$; $I_{BQ} \leftarrow \frac{I_{CQ}}{\beta}$; I_{BQ} ↓ dc current ↓ dc analysic

hib ⇓ $= \frac{V_T}{I_{EQ}}$ $= —$

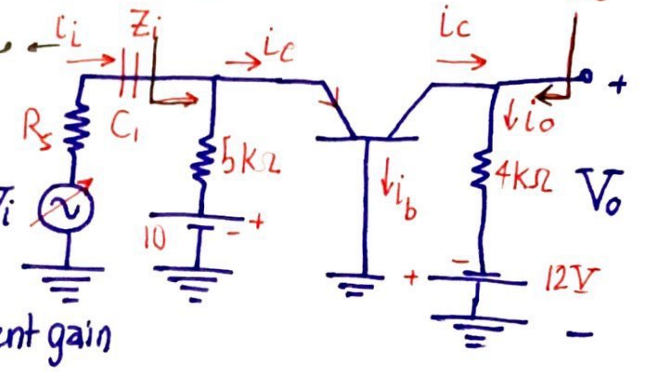
hfe ⇓ $\frac{i_{output}}{i_{input}} = \frac{i_c}{i_b} = \beta$

$25.69\,mV \leftarrow V_T$

$$= \frac{V_T}{\frac{I_{CQ}}{h_{fe}}} = \frac{h_{fe} V_T}{I_{CQ}} = \frac{\beta V_T}{I_{CQ}}$$

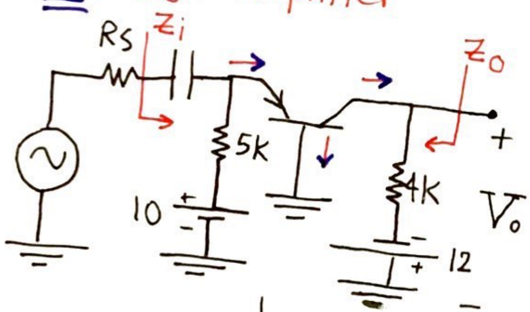
Example: BJT Amplifier Analysis

Analyse



1. $A_V = V_o/V_i$, Small signal voltage gain
2. $A_i = i_o/i_i$, Small signal current gain
3. Z_i Input Impedance — Independent sources يعني kill
4. Z_o output //

CB BJT Amplifier



($R_s = 0$ when, $R_s \neq 0$)

Find $A_V = \frac{V_o}{V_i}$

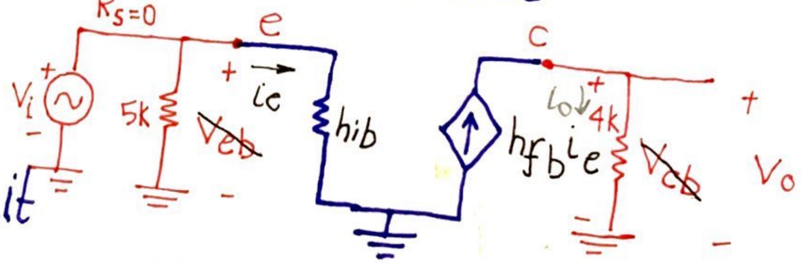
$A_i = \frac{i_o}{i_i}$

Z_i & Z_o (from Analysis)

↓ ac ss eq. Circuit (ss → Small signal)

- Caps Short
- dc sources killed
- BJT - h-param eq. circuit

Common Base



$V_o = V_{on\,4k} = i_o \cdot 4k = h_{fb} i_e 4k$

$A_V = \frac{V_o}{V_i}$

$V_o = h_{fb} i_e \cdot 4k$

$i_e = \frac{V_i}{hib}$

$A_V = \frac{h_{fb}\, i_e\, 4k}{i_e\, hib}$

$A_V = \frac{V_o}{i_e} \cdot \frac{i_e}{V_i} = \frac{h_{fb}\; 4k}{hib}$

$= 286$

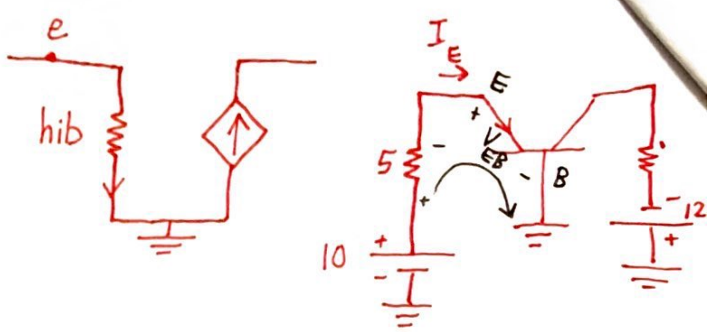
$A_i = \frac{i_o}{i_i}$

$i_o = h_{fb} i_e$

$i_e = i_i \cdot \frac{5k}{5k + hib}$ current divider rule

$A_i = h_{fb} \cdot \frac{5k}{5k + hib} = 0.997$

$h_{ib} = \frac{V_T}{I_{EQ}}$ ← dc analysis
1 ac Sources killed
2 Caps open



$10 = I_E 5K + V_{EB}$ → 0.7

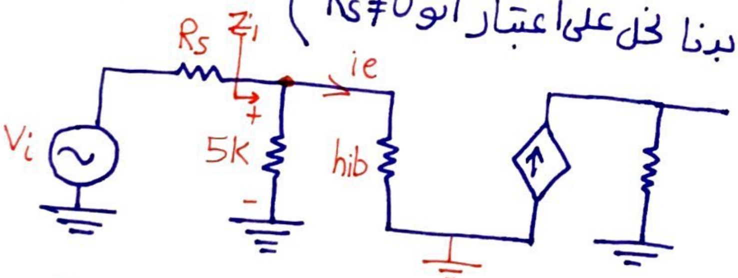
$I_{EQ} = \frac{10-0.7}{5K} = 1.86\,mA$ ⟹ $h_{ib} = \frac{25.69\,mV}{1.86\,mA} = 13.8118$

$Z_i \Rightarrow 5K // h_{ib}$

$Z_o| \Rightarrow 4k$

$V_i = 0 \Rightarrow i_e = 0$

(هسا بدنا نحل على اعتبار انو $R_s \neq 0$)



Part 2

$V_e = \frac{Z_i}{Z_i + R_s} \cdot V_i$; $i_e = \frac{V_e}{h_{ib}}$

تأثير قيمة Rs هو تقليل قيمة i_e واذا قلت i_e بقل V_o ← بقل الـ Voltage gain

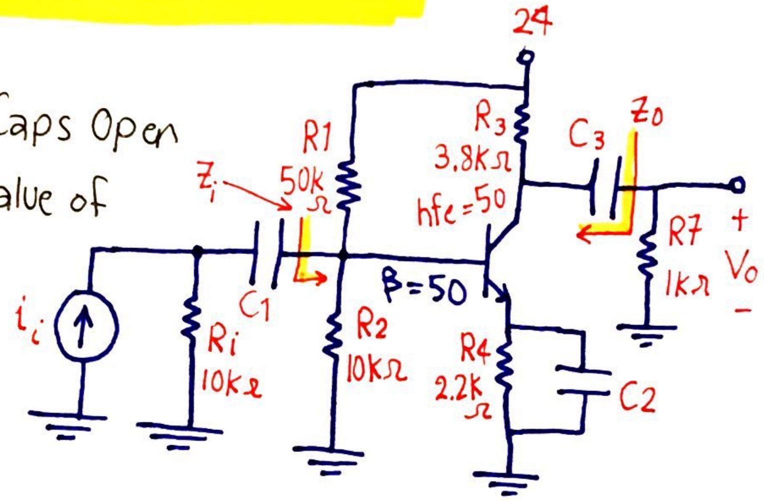
Voltage gains ← تتأثر سلباً مع زيادة Rs .

$R_s = 50\Omega$	$R_s = 0\Omega$
$A_V = 62.5$	$A_V = 286$
$R_s = 10K$	
$A_V = 0.4$	

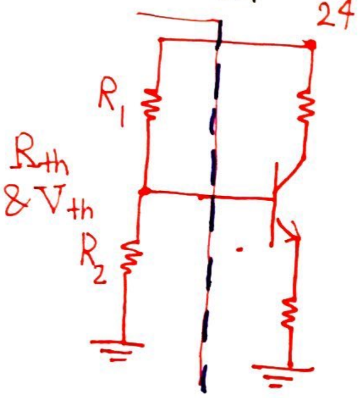
Example : Common Emitter (CE)

From DC analysis : Caps Open

we find Q-point & value of

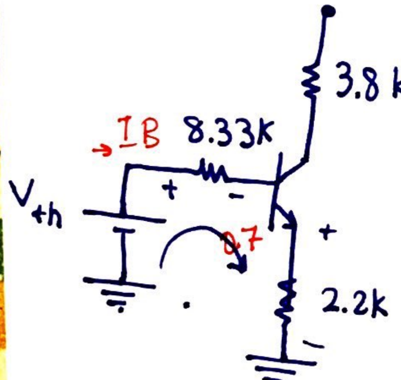


$$hie = \frac{V_T}{I_{BQ}} =$$



$$V_{th} = V_{oc} = \frac{R_2}{R_1 + R_2} \times 24 = \frac{10}{60} \times 24 = 4V$$

$$R_{th} = R_1 // R_2 = \frac{10 \times 50}{60} = \frac{500}{60} = 8.33\Omega$$



$$I_{BQ} = \frac{4 - 0.7}{8.33k + 2.2k(\beta+1)}$$

نقطع هاي

$$4 = 8.33k\, I_B + V_{BE} + 2.2k\, I_E$$

$$I_E = (1+\beta) I_B$$

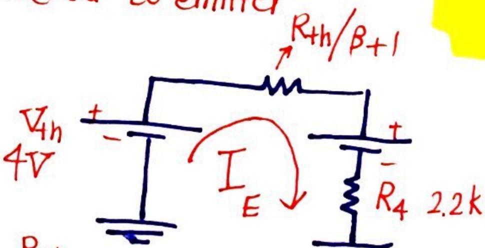
$$hie = \frac{V_T}{I_{BQ}}$$

Here we have base reflected to emitter

dafs

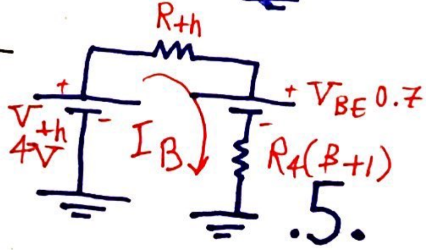
$$I_B \Rightarrow I_E = (\beta+1) I_B$$

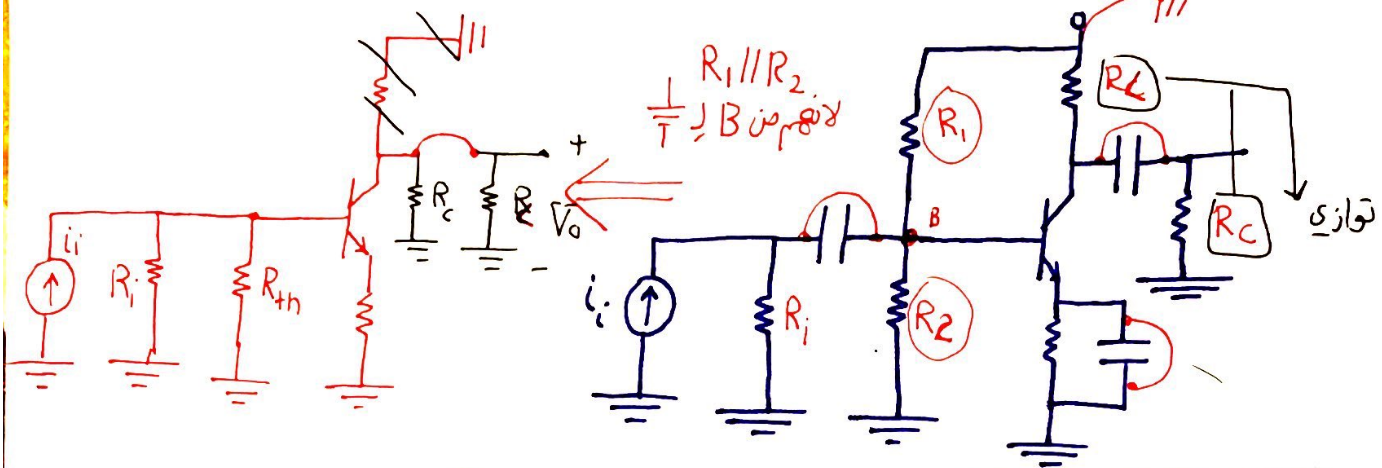
$$R_B \Rightarrow \frac{R_B}{\beta+1}$$

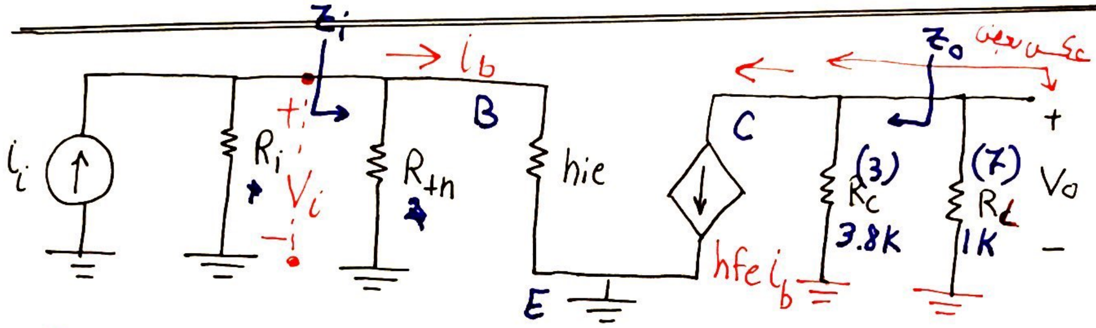


$$I_E \Rightarrow I_B = \frac{I_E}{(\beta+1)}$$

$$R_E \Rightarrow R_E(\beta+1)$$







$$A_V = \frac{V_o}{V_i} \Rightarrow V_o = -h_{fe} i_b (R_C // R_L) \Rightarrow \frac{V_o}{i_b} = \ldots (1)$$

$$i_b = \frac{v_i}{h_{ie}} \Rightarrow \frac{i_b}{v_i} = \frac{1}{h_{ie}} \quad (2)$$

$$A_v = -h_{fe} (R_C // R_L) \cdot \frac{1}{h_{ie}} = -42.7$$

* $Z_I = R_{th} // h_{ie}$

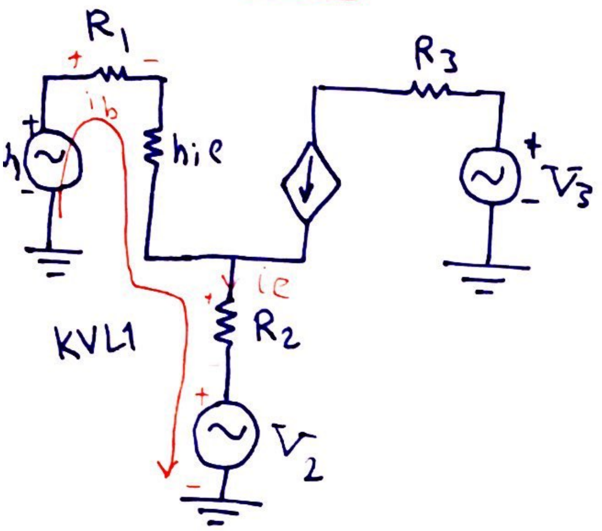
$= 8.33K // 928 K$

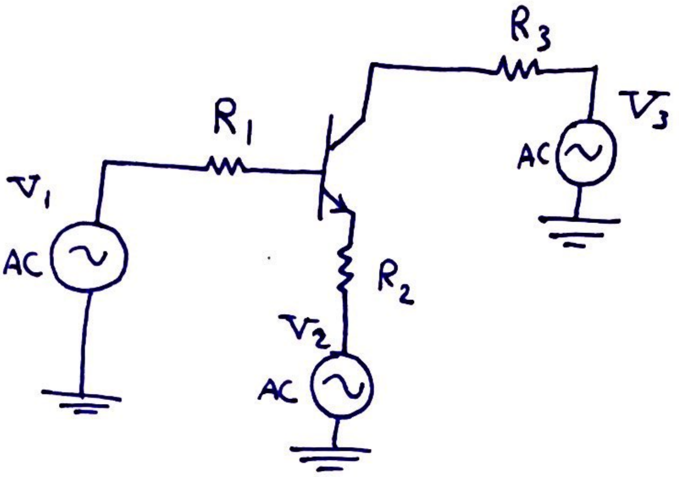
* $Z_o \Big|_{h_{fe} i_b = 0,\; v_i = 0} = R_3 = 3.8K$

$$A_i = \frac{i_o}{i_i} \Rightarrow i_b = i_i \left(\frac{R_i // R_{th}}{(R_I // R_{th}) + h_{ie}} \right)$$

$$i_o = -h_{fe}\, i_b \left(\frac{R_3}{R_3 + R_7} \right)$$

CE



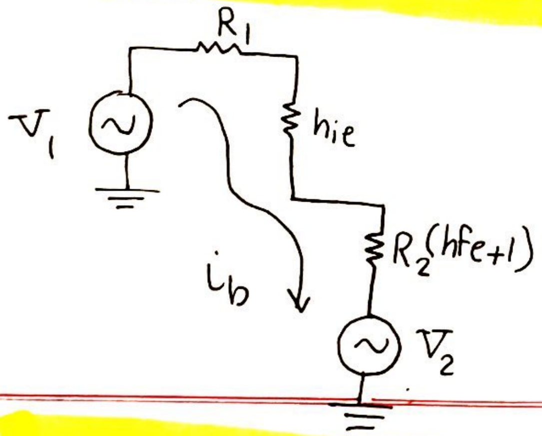


KVL1 : $V_1 = I_b R_1 + I_b h_{ie} + I_e R_2 + V_2$

$i_e = i_b(h_{fe}+1) = i_b(\beta+1)$

$$I_b = \frac{V_1 + -V_2}{R_1 + h_{ie} + R_2(i_b(h_{fe}+1))}$$

ملاحظة من جهة الCollector
"Collector Eq. Circuit"
ما تغير التيار اللي مارر فيها لان $V_C \cong V_E$



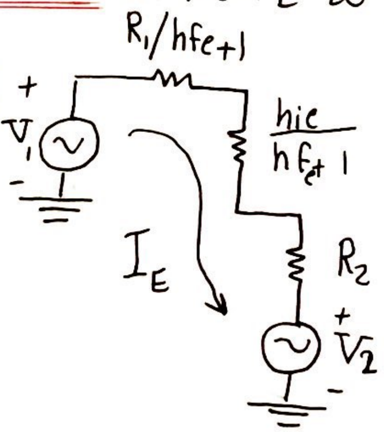
Base eq. circuit

$R_2 \rightarrow R_2(h_{fe}+1)$

R_1, $h_{ie} \rightarrow$ the same

Reflection from E to B

$$I_e = \frac{V_1 - V_2}{\frac{R_1 + h_{ie}}{h_{fe}+1} + R_2}$$



Emitter eq. Circuit

(Base to Emitter) Reflection

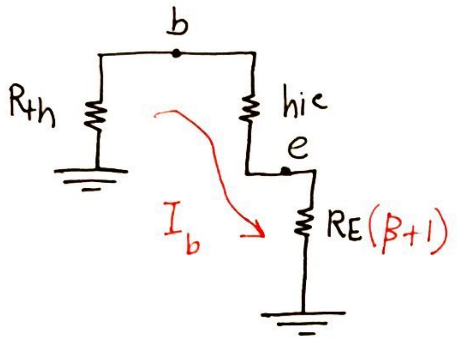
$R_1, h_{ie} \rightarrow \frac{R_1}{h_{fe}+1}, \frac{h_{ie}}{h_{fe}+1}$

$R_2 \rightarrow$ the same

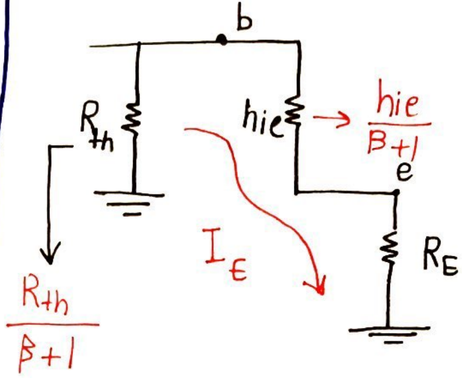
Electronics : ENEE236 : L12 → CC ampilfier

Impedance Reflection

Emitter to Base

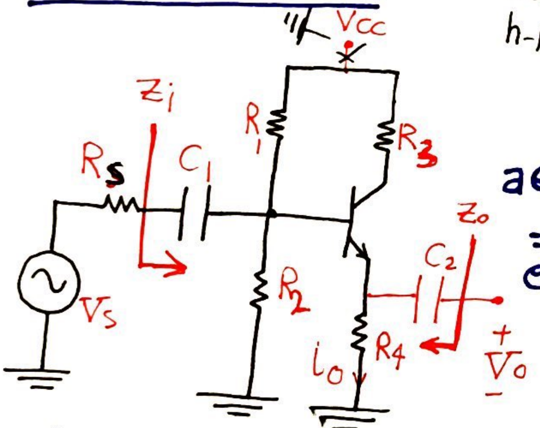


Base to Emitter

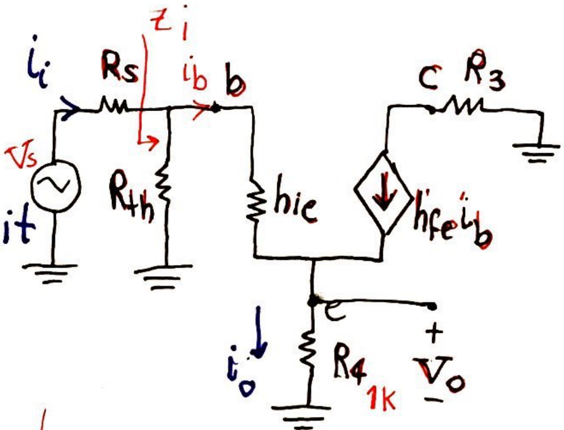


CC Amp. Example

kill dc
Caps open
h-parameter



ac SS ⟹ eq. Circuit



$h_{ie} = 1k\Omega = \frac{V_T}{I_{BQ}}$

$h_{fe} = \beta = 50$

Find A_v, A_i, Z_i, Z_o المطلوب

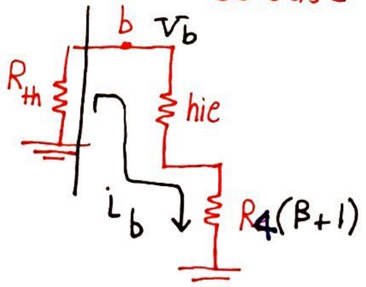
$A_v = \frac{V_o}{V_i} \Rightarrow$

$V_o = i_e \cdot 1k$

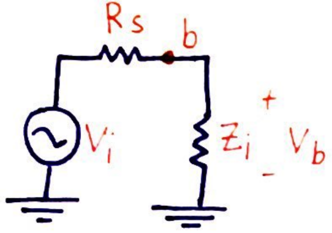
$i_e = i_b(h_{fe}+1)$

$i_b =$ ⟹

Emitter to Base



$$i_b = \frac{V_b}{h_{ie} + R_e(h_{fe}+1)}$$



$$V_b = \frac{Z_i}{Z_i + R_s} V_i$$

$$A_V = \frac{V_o}{i_e} \times \frac{i_e}{i_b} \times \frac{i_b}{V_b} \times \frac{V_b}{V_i}$$

✓

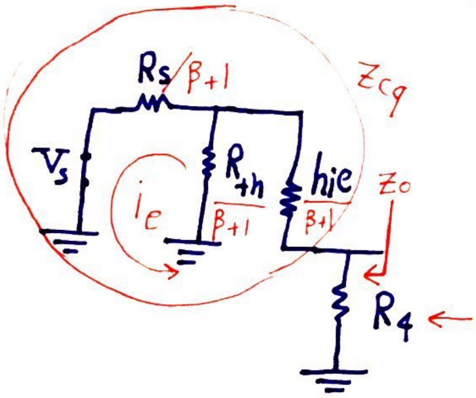
$$= 1K \times (h_{fe}+1) \times \frac{1}{h_{ie} + R_e(h_{fe}+1)} \times \frac{Z_i}{Z_i + R_s}$$

$$= 0.915 < 1$$

$$Z_i = R_{th} \,//\, [h_{ie} + R_4(\beta+1)] \checkmark$$

$= 13.66 K\Omega$ (high)

$Z_o |_{V_i = 0}$? Z_o thevinin Impedence.



$$Z_o = R_4 \,//\, Z_{eq}$$

$$= R_4 \,//\left[\frac{h_{ie} + (R_s // R_{th})}{\beta+1}\right] = 36.8\Omega \text{ (low)}$$

$$A_i = \frac{i_o}{i_i}$$

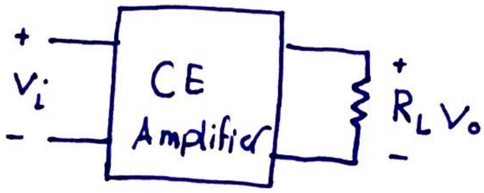
// $i_o = i_e = i_b(\beta+1)$

$$i_b = i_i\left(\frac{R_{th}}{R_{th} + h_{ie} + R_4(\beta+1)}\right)$$

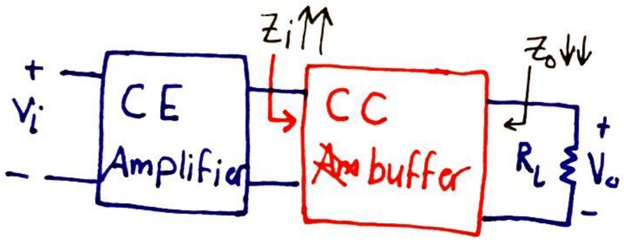
$$A_i = \frac{i_o}{i_b} \times \frac{i_b}{i_i}$$

$$A_i = \underset{h_{fe}+1}{(\beta+1)} * \left(\frac{R_{th}}{R_{th} + h_{ie} + R_4(\beta+1)}\right) = 13.39 > 1$$

CC Amplifier as a buffer



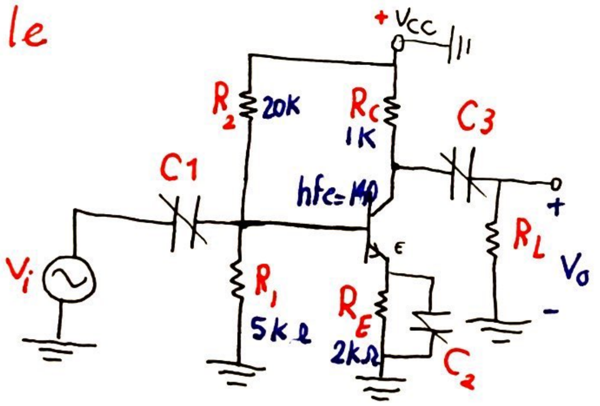
RL affccats Av of Amplifiers ⇒ loading effect
↓
Voltage gain



hie = 1000 Ω
hfe = 140

Emitter follower
$A_v \cong 1$
$A_i > 1$

Example

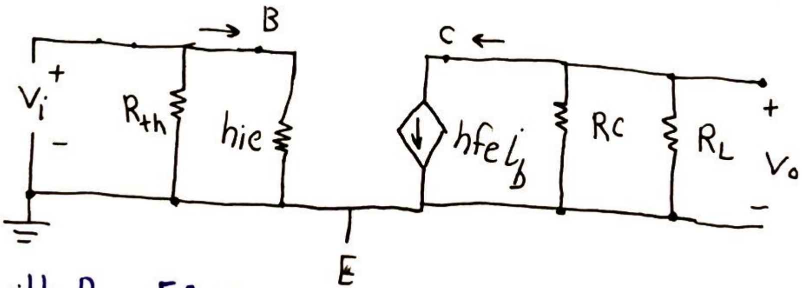


- effect of load (RL) on A_V
- then use buffer & see reducing effect

[1] with $R_L = \infty$

$V_o = -h_{fe}\, i_b \cdot (R_C)$

$i_b = \frac{V_i}{hie}$



$AV = \frac{V_o}{V_i} = \frac{V_o}{i_b} \cdot \frac{i_b}{V_i}$

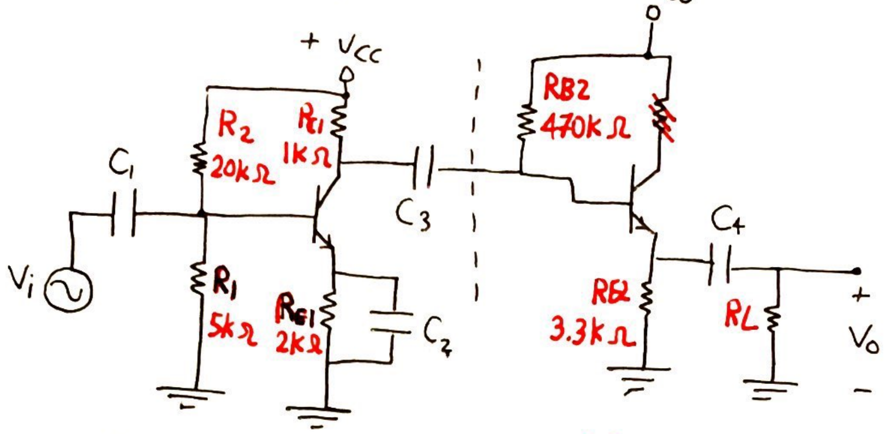
$= (-h_{fe} R_C) \cdot \frac{1}{hie} = 140$

[2] with $R_L = 50\,\Omega$

$V_o = (-h_{fe} R_C \,//\, R_L)$

$AV = \frac{V_o}{V_i} = (-h_{fe} R_C // R_L) \cdot \frac{1}{hie} = -6.87$ (Reduced from -140 to -6.87)

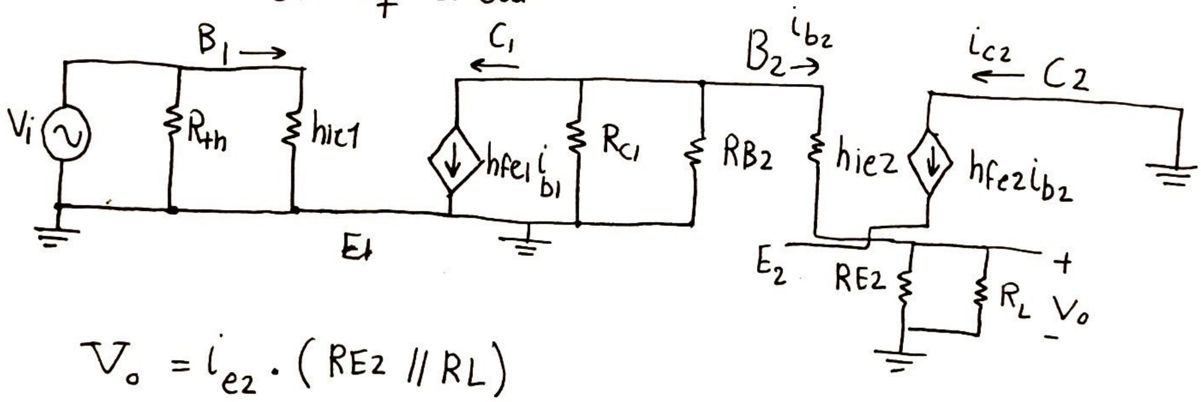
Amplifier + Buffer + load



$h_{fe1} = 140$
$h_{ie1} = 1k\Omega$
Stage 1

$h_{fe_2} = 140$
$h_{ie2} = 2.24k\Omega$
Stage 2

ac ss eq. Circuit



$$V_o = i_{e2} \cdot (R_{E2} \,//\, R_L)$$

$$i_{e2} = i_{b2}(1+\beta) = i_{b2}(1+h_{fe2})$$

$$i_{b2} = -h_{fe1} i_{b1} \cdot \frac{(R_{C1} \,//\, R_{B2})}{((R_{C1} // R_{B2}) + (h_{ie2} + (R \;//\; R\;)(1+h_{fe2})))}$$

$$i_{b1} = \frac{V_i}{h_{ie2}}$$

$$A_V = \frac{V_o}{V_i} = \frac{V_o}{i_{e2}} \cdot \frac{i_{e2}}{i_{b2}} \cdot \frac{i_{b2}}{i_{b1}} \cdot \frac{i_{b1}}{V_i} = -95.6$$

(Much Better)

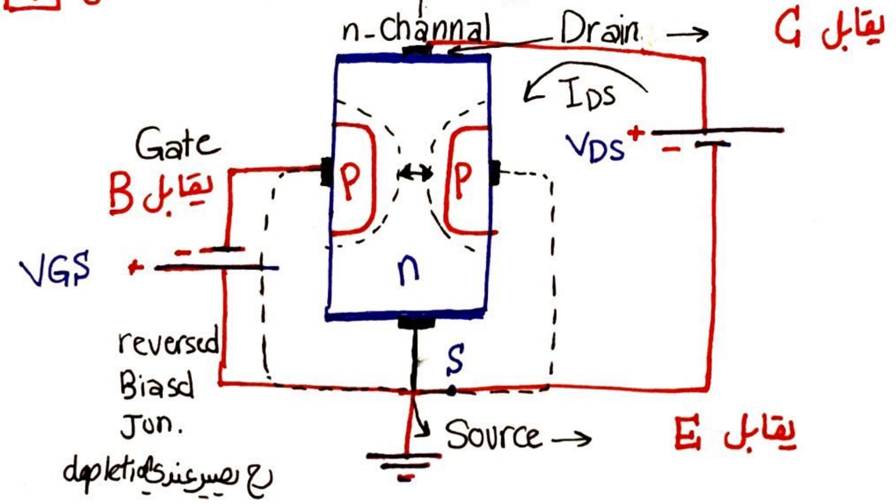
Electronics : ENEE236 → L13 : Part 2

Field EFFECT Transistor → FET VS. BJT

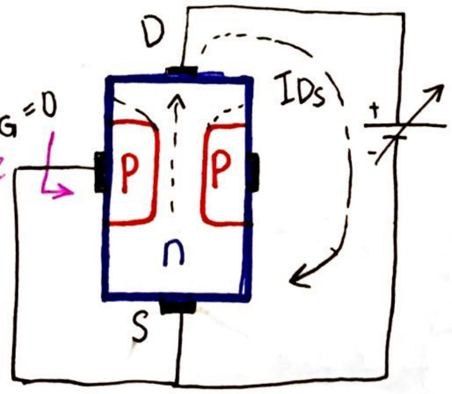
"Advantages"	"Disadvantages"
+ Z_{in} ↑↑	− ↓↓ Voltage gain
+ Manufactaring Is easier	− Poor frequancy response
+ Size Small	− Eelectro static discharg (ESD) Sensitivity.

FET Types :
- JFET (J → Junction)
  - n-channel
  - p-channel
- MosFET (Metal oxid semicoductor)
  - Type: Depletion "D-MOSFET" → n, p Channe
  - Enhancement "E-MOSFET" → n, p

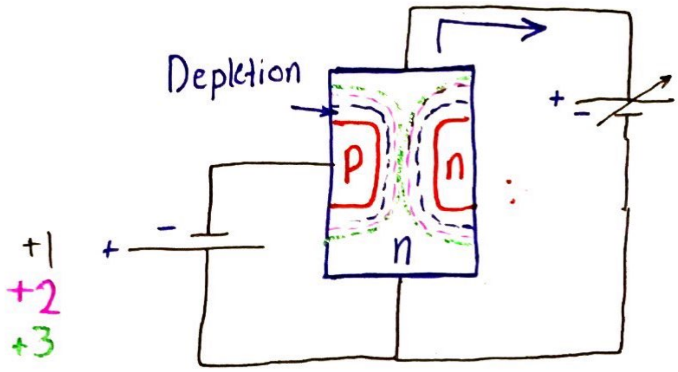
1 Junction Field Effect Type Transistor "JFET"

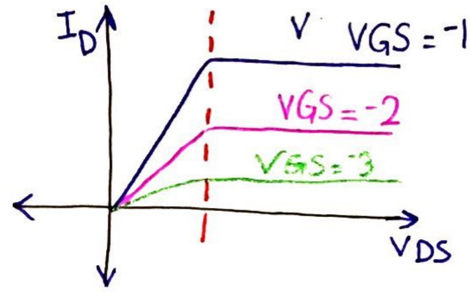


Input Impedance $= \frac{V_{GS}}{I=0} = \infty$



$I_{DS} = I_S = I_{DS}$





هسا لنفرض انا ثبتت ~~التيار~~ الجهد جهة الـ Gate وعم بغير ~~بالتيار~~ الجهد جهة Drain في منطقة

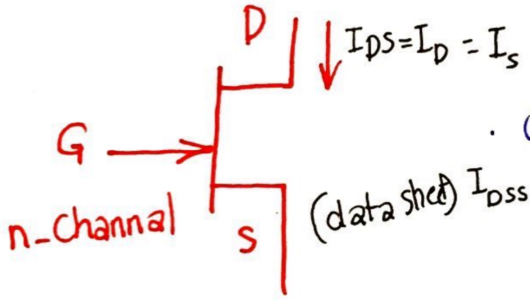
الـ Depletion رح تزيد وبتخلي الجهد عندي ثبات بالتيار

بمرحلة ما ممكن احط قيمة لـ V_{GS} بتخلي الـ Channal closed وبصير زي الـ Cutoff

---

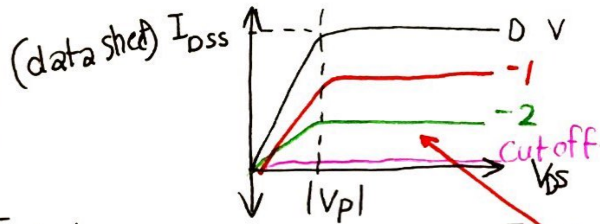
** ملاحظة: $I_G = 0$ ⇐ "دائمًا" لان الـ Pn Junction عليها reverse biased

وهاد اللي بخلي Z_{in} عالي



← لما تكون $V_G = 0$ كأنه التيار بتدفق بأكبر قدر ممكن.

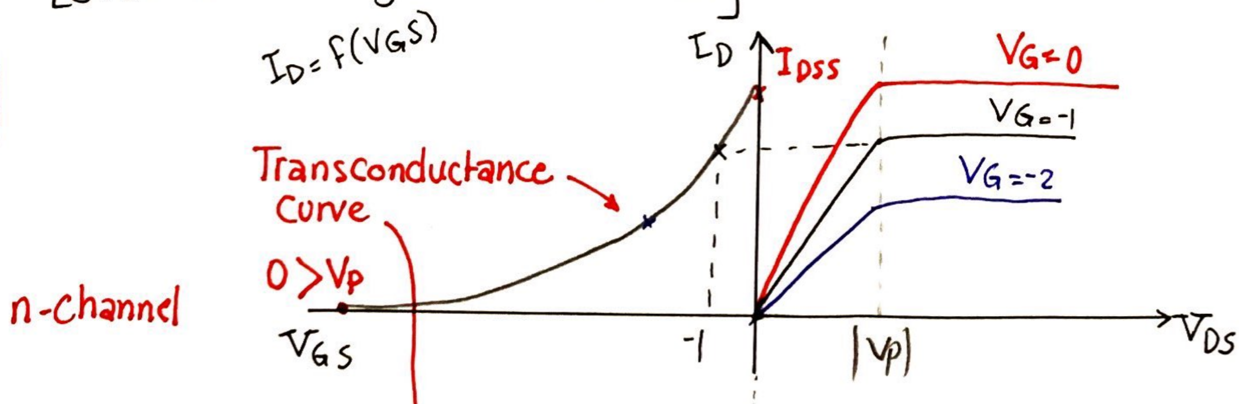
(DSS) ↳ Drain Saturation Current

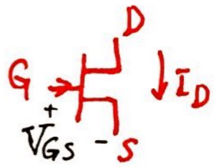


$V_{GS} = V_p$ ⇒ قمة السالبة كأني سكرت الحنفية وما في تدفق.

[V_p: هي القيمة اللي بصير عندها الـ T كأنه مغلق وما بمرر تيار] Pinch off Voltage "region"

[JFET is a voltage control device]



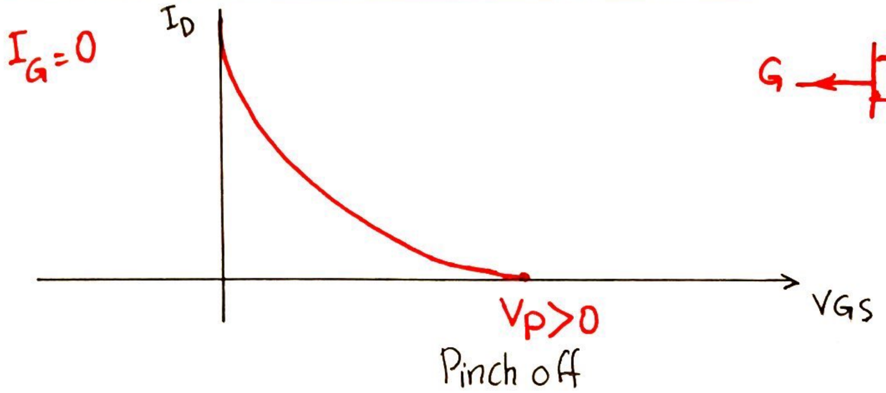


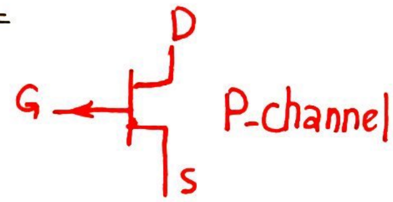
$$I_D = I_{DS} = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2$$ "معادلته" ***

data sheet

نلاحظ اذا $V_p = V_{GS}$ ⇐ $I_D = 0$

P- channal





N-Channel → $V_P < V_{GS} \leq 0$

$I_{DSS} \geq I_D > 0$

P-Channel → $0 \leq V_{GS} < V_P$

$0 < I_D \leq I_{DSS}$

المعادلة نفسها

$$I_D = I_{DSS}\left(1 - \frac{V_G}{V_P}\right)^2$$

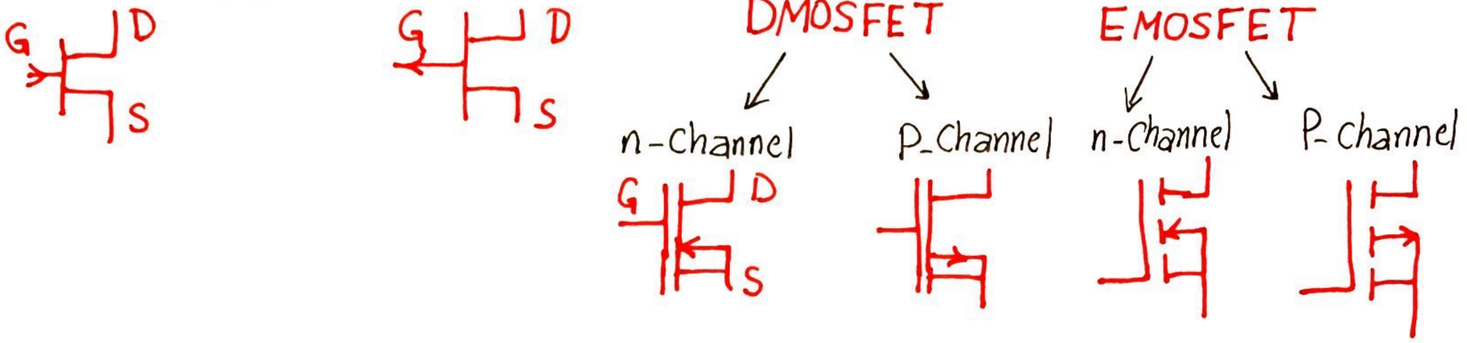
Electronics : ENEE 236 ⟹ L14 - JFET Baiasing

JFET → n-Channel, P-Channel

MOSFET → ~~n-Channel~~ DMOSFET, ~~P-Channel~~ EMOSFET

DMOSFET → n-Channel, P-Channel

EMOSFET → n-Channel, P-Channel



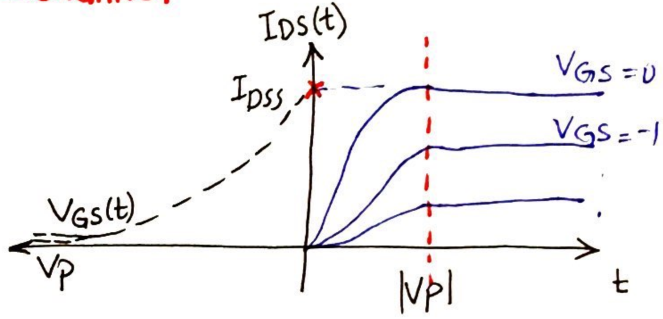
$V_P = \begin{cases} \text{negative value for n-channel} \\ \text{Positive value for P-channel} \end{cases}$

$$\left[I_{DS}(t) = I_{DSS}\left(1 - \frac{V_{GS}(t)}{V_P}\right)^2 \right]$$

In pinch off Region

$V_P < V_{GS} \leq 0$ "n-channel"

$|V_{DS}| > |V_P| - |V_{GS}|$ | "P-channel" $V_P < V_{GS} \leq 0$



Common JFET Biasing Circuit

- Fixed-Bias
- Self-Bias
- Voltage-Divider Bias

Important

For All FETs:
$I_G \cong 0A$, $I_D = I_S = I_{DS}$

For All JFETs:
$I_{DS}(t) = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2$

→ DMOS. نفسها للـ

1 Fixed-Bias : I_{DSS} ✓, V_P ✓

V_{GS}? I_D? V_{DS}?

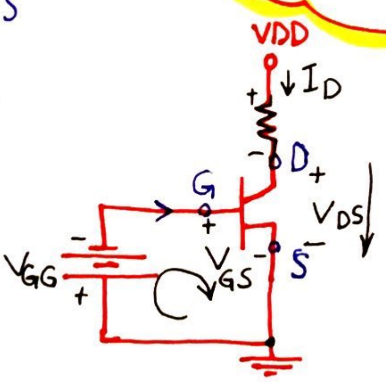
$V_{GG} + V_{GS} = 0 \Rightarrow V_{GS} = -V_{GG}$

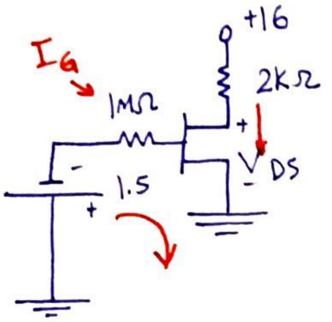
$V_{DD} = I_D R_D + V_{DS}$

$V_{DS} = V_D$

$V_{GS} = V_G$

$\boxed{0 = V_S}$ فقط





Example

$I_{DSS} = 10\ mA$
$V_P = -4$

$V_{GS} = -1.5$ Volt

$$I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2 = 10\,mA\left(1 - \frac{-1.5}{-4}\right)^2$$

$$= 3.9\ mA$$

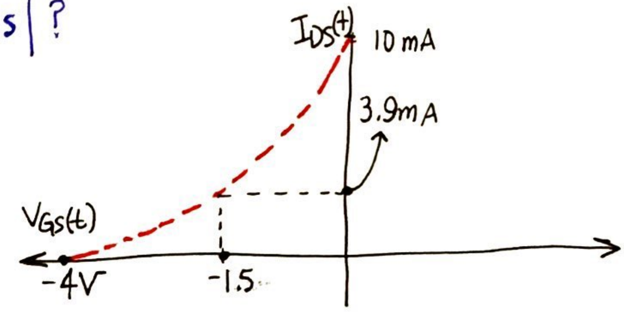
$$V_{DS} = 16 - I_D \cdot 2K = 8.2\ V$$

Check $|V_{DS}| > |V_P| - |V_{GS}|$?

$8.2 > |4| - 1.5$

Graphical method

- $V_{DS} = I_{DSS} - \left(1 - \frac{V_{GS}}{V_P}\right)^2$
- $V_{GS} = -1.5$ Fixd



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2 Self - Bias Configuration

$$0 + V_{GS} + I_D R_S = 0$$

(I_S)

$V_{GS} = V_G - V_S = 0 - V_S = -V_S$

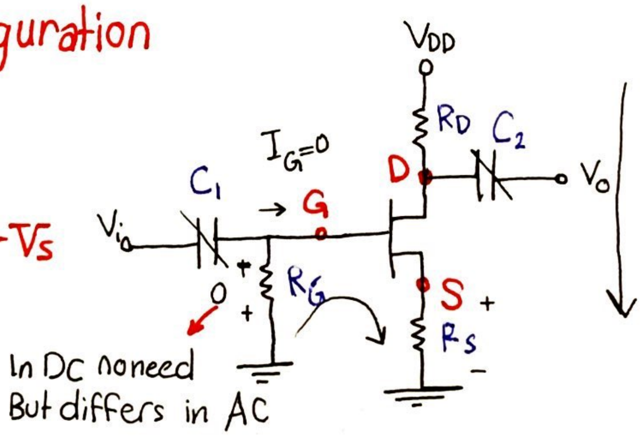
$V_S = I_D R_S$

$V_{GS} = -I_D R_S$

$V_D = V_{DD} - I_D R_D$

$V_{DS} = V_D - V_S$

$$= V_{DD} - I_D R_D - I_D R_S = V_{DD} - I_D(R_D + R_S)$$

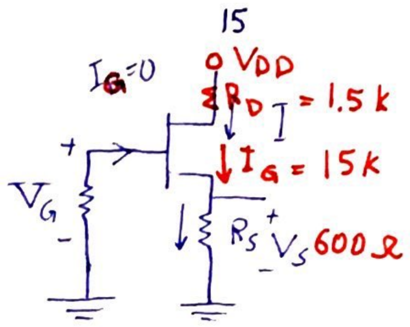


$V_{GS} = V_G - V_S$ ($V_G \to 0$)

$V_{GS} = 0 - I_S R_S$

$V_{GS} = -I_S R_S$

$V_{GS} = -600 I_S$ ($I_S \Leftrightarrow I_D$)



$$I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2$$

$$= 10mA\left(1 - \frac{-600 I_D}{-4}\right)^2 \Rightarrow \text{معادلة تربيعية} \; \frac{-b \mp \sqrt{b^2 - 4ac}}{2a}$$

$I_{D1,2}$ → 14.77 mA $> I_{DSS}$

$I_{D1,2}$ → 3.0 mA $< I_{DSS}$ ✓ ، الحد

$15 - 1.5k I_D - V_{DS} - 0.6k I_D = 0$

$V_{DS} = 10.2V$

I_{DSS} : IS the Maximum value and it's 10 mA which mean that 14.77 > I_{DSS} the other solution is 3 mA and it's < I_{DSS} then it's accepted!

$V_{GS} = -600 \cdot 3mA$ (تعتمد على I_D)

$= -1800mV = -1.8V$

$|V_{DS}| > |V_P| - |V_{GS}|$

$10.2 > |4| - |1.8|$ ✓ "Cheaked"

---

2 Graphical method : ⇒ Graph بنستخدم ال $I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2$ بدل ما نستخدم المعادلة

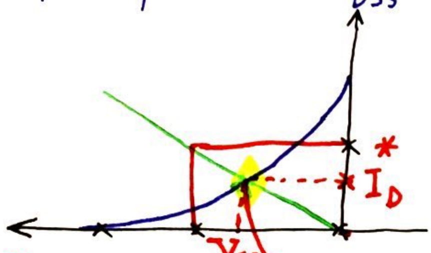
$V_{GS} = (-0.6K) I_{DS}$

لو حطينا $I_{DS} = 0 \Leftarrow V_{GS} = 0$ يعني

بتمر بال origin بتطلع *

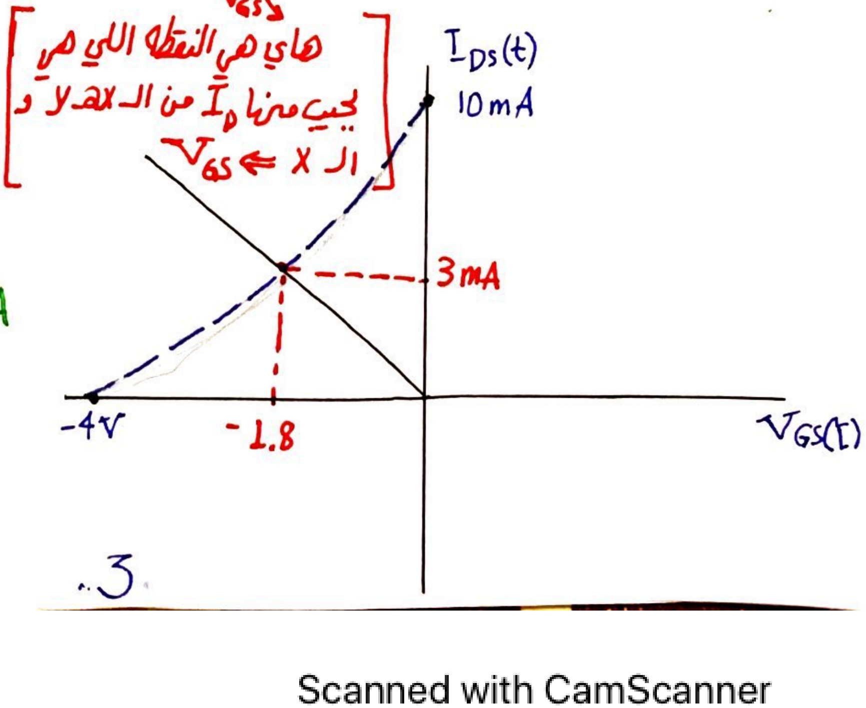
نعطاي قيمة ل I_{DS} مثلاً 5

ولنفرض طلع $V_{GS} = -3$



When $V_{GS} = 0 \rightarrow I_{DS} = 0$

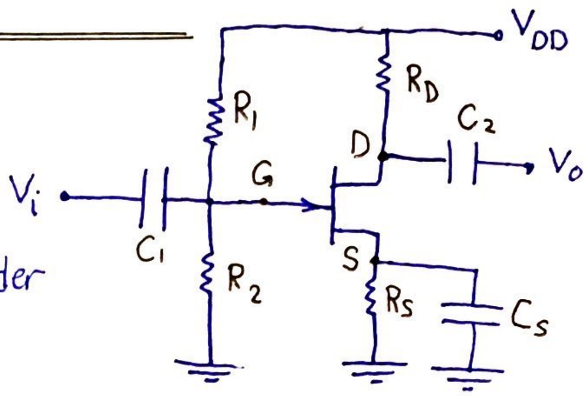
When $V_{GS} = -3 \rightarrow I_{DS} = 5mA$



3 Voltage_Divider Bias

$I_G = 0 mA$

I_D responds to changes in V_{GS}



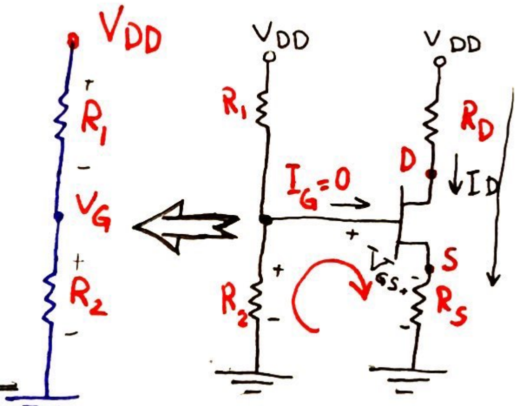
V_G is equal to the voltage across divider resistor R_2

$$V_G = \frac{R_2}{R_1 + R_2} \cdot V_{DD}$$

$$V_S = I_D R_S$$

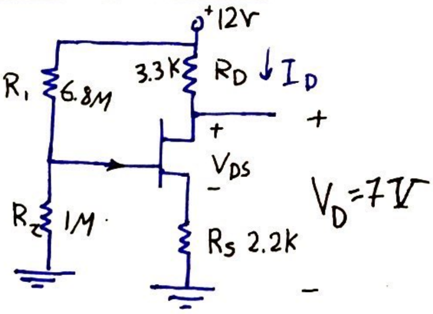
Using kirchhoff's law: $V_{GS} = V_G - I_D R_s$

$$V_{GS} = \frac{R_2}{R_1 + R_2} \cdot V_{DD} - I_D R_s$$



Example

I_D, V_{GS} ?

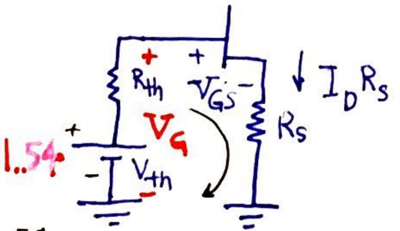


$$I_D = \frac{12 - 7}{3.3K} = \frac{5}{3.3K} = \boxed{1.52 mA}$$

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

⇕

$$V_G = \frac{1M}{7.8M} \cdot 12 = 1.54$$



$KVL \Rightarrow V_G - I_D R_S = V_{GS}$

$1.54 - (1.52m)(2.2k) = V_{GS} =$

$V_{GS} = 1.54 - 3.344 = -1.8 V$

$$R_{th} = R_1 // R_2$$
$$V_{th} = \frac{R_2}{R_1 + R_2} \cdot V_G$$

طريقة الدكتور

$V_{th} = V_{GS} + I_D R_s$

$V_{GS} = V_{th} - I_D R_s$

$I_D = I_{DSS} \times \left(1 - \frac{V_{GS}}{V_P}\right)^2$

$I_D = I_{DSS}\left(1 - \frac{V_{th} - I_D R_s}{V_P}\right)^2$

أو

$$\left[\frac{V_{th} - V_{GS}}{R_s} = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2\right]$$

"تكملة السؤال "الجواب

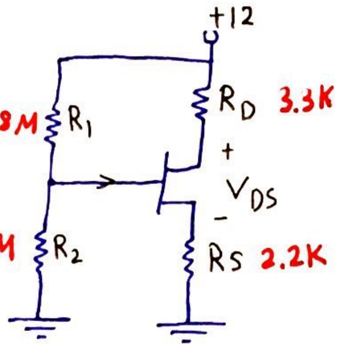
$V_S = I_D R_s = (1.52mA) \times (2.2k) = 3.34V$

$V_G = \frac{1M}{1M + 6M} \cdot 15 = 1.54V$

هسا لو V_D مش معروفة عندي بضطر اعمل معادلة تربيعية

$$\left[V_{GS} = \frac{R_2}{R_1 + R_2} \cdot V_{DD} - I_D R_s\right]$$

Example_ V_D unknown



$$V_{GS} = \frac{R_2}{R_1+R_2} \cdot V_{DD} - I_D R_s$$

$$V_{GS} = 1.54 - I_D R_s$$

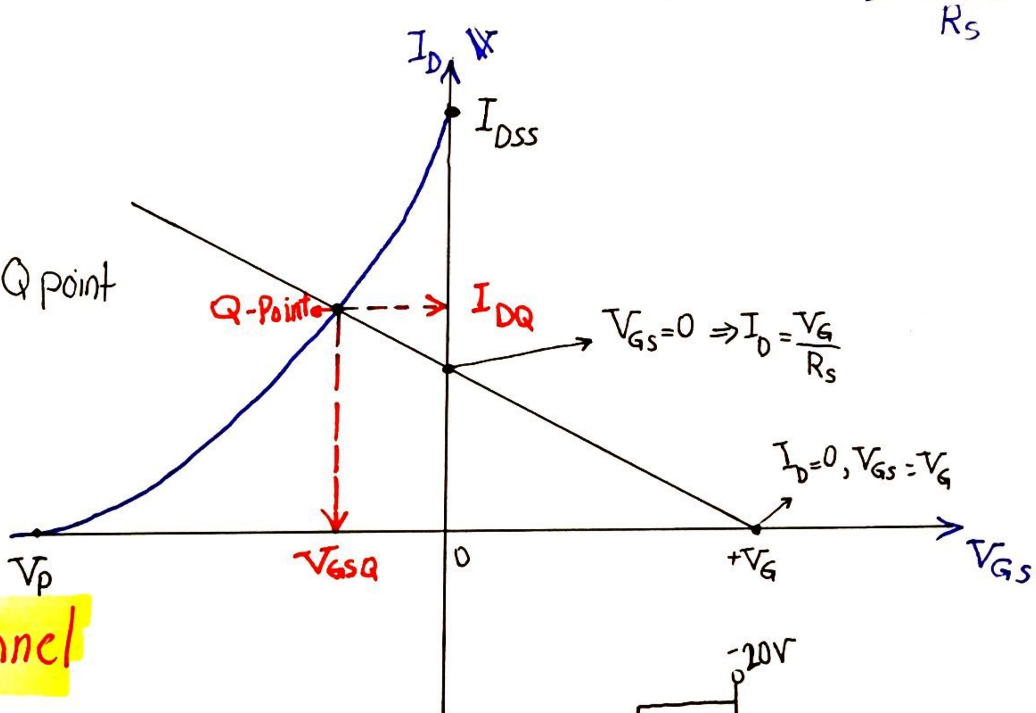
When $I_D = 0 \Rightarrow V_{GS} = 1.54$

When $V_{GS} = 0 \Rightarrow I_D = \frac{1.54}{R_s}$

$$I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2$$

$$= I_{DSS}\left(1 - \frac{1.54 - I_D R_s}{V_P}\right)^2$$

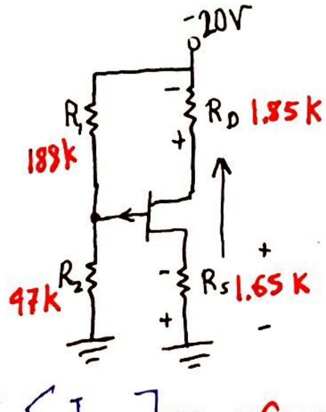
Voltage _Divider Q point



Example p_Channel

$V_P = 5V > 0$

$I_{DSS} = 18mA$



ماينس ماينس

$$V_{GS} = V_G - V_S = \frac{R_2}{R_1+R_2} \cdot 20 + I_D R_s$$

$$V_{GS} = -4 + I_D R_s$$

$$I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2$$

$$= I_{DSS}\left(1 - \frac{-4 + I_D R_s}{5}\right)^2$$

$$= 18mA\left(1 - \frac{-4 + I_D \times 1.65}{5}\right)^2$$

$I_{D1} = 4.7mA$ ✓ $< I_{DSS}$

$I_{D2} = 7.4mA$ ✓ $< I_{DSS}$

ما بتقرر الا لما تشوف V_{GS} فـ بتشوف كل وحدة منهم بتعطيني كم؟

$V_{GS} = -4 + (4.7m)(1.65k) = 3.75V$

$V_{GS} = -4 + (7.4m)(1.65k) = 8.21V$

$V_P = 5$ لازم يكون اصغر

فـ I_{D1} ✓

Midpoint Bias : For maximum Symmetrical Swing

- Place Qpoint in the midde point of the transfer charactristic to allow for Maximum swing between I_{DSS} & Zero

[1] let $I_D = 0.5 I_{DSS}$

$$0.5\, I_{DSS} = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2$$

$$0.5 = \left(1 - \frac{V_{GS}}{V_P}\right)^2$$

$$\sqrt{0.5} = 1 - \frac{V_{GS}}{V_P} \Rightarrow \frac{V_{GS}}{V_P} = 1 - \sqrt{0.5}$$

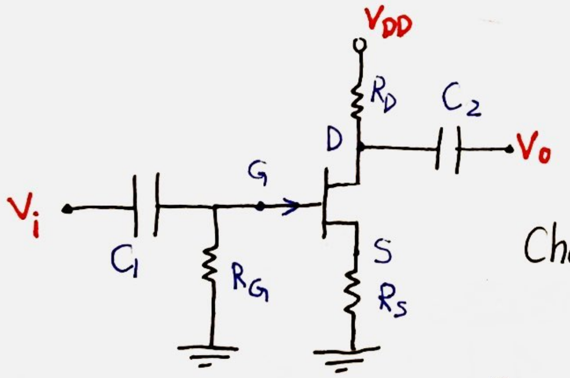
$$V_{GS} = V_P\left(1 - \sqrt{0.5}\right)$$

$$V_{GS} = V_P\,(0.2928)$$

$$\therefore V_{GS} \cong \frac{V_P}{3.41}$$

---

[2] let $V_D = 0.5\, V_{DD}$



$V_P = V_{GS}(\text{off}) = -3V$

$I_{DSS} = 12\, mA$

Choose R_D & R_S for mid point Bias

$V_D = \frac{1}{2} V_{DD}$, $6mA = I_Q$ بنا

$= 6V$

$I_D = 0.5\, I_{DSS} = 6\, mA$

$V_D = 0.5\, V_{DD} = 6V$

$$V_{GS} = \frac{V_{GS}(\text{off})}{3.4} = \frac{-3}{3.4} = -0.882\,V$$

$= V_G - V_S$

$V_{GS} = 0 - V_S$

$V_S = -(-0.882)$

$$R_S = \frac{V_S}{I_D} = \frac{0.882}{6mA} = 147\,\Omega$$

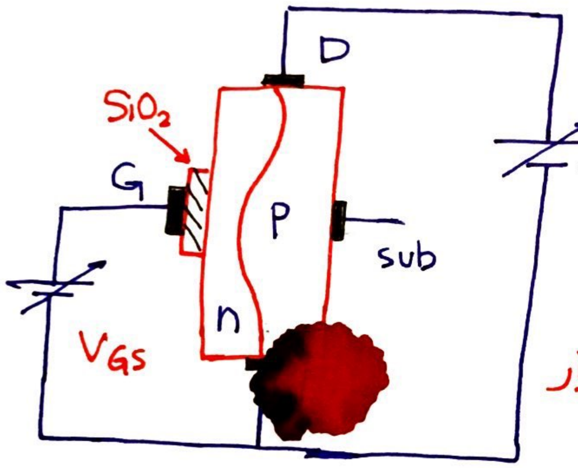
$$V_{DD} - I_D R_D - V_D = 0 \Rightarrow R_D = \frac{V_{DD} - V_D}{I_D} = 1K\Omega$$

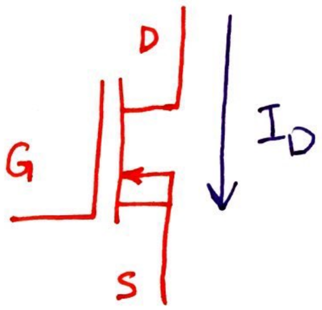
Electronics : ENEE236 → L15 : Part 2

Metal Oxide Semiconductor

[1] DMOSFET : Depletion type Mosfet

[2] EMOSFET : Enhancement type Mosfet





كل ما نزيد الالكترونات ف من جهة G " RB " بيكسر التيار
لما يوصل لـ Vp

الاختلاف الرئيسي بينه وبين JFET انو ما في Pn Junction ←

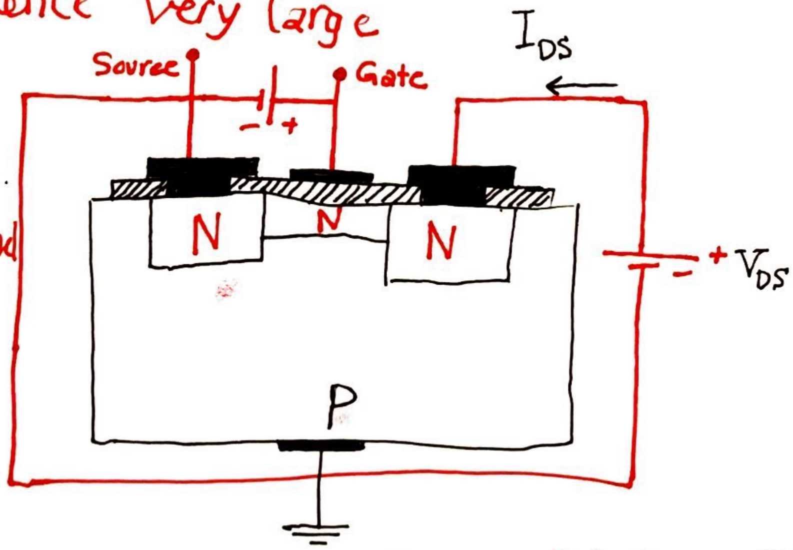
Instead, the gate of the MosFET in isolaled form the channel by a Silicon dioxide (SiO_2) Large.

Due to this the Input resistance of MOSFET is greater than JFET

Input Z "Impedence" very large

Depletion type Mos.

Construction of n-Channel DMOFET



اذا حطينا Voltage>0 من جهة Gate ف بجذب P بالتالي بزيد الـ Conduction electrones يعني بزيد التيار I_{DSS}

Metal Oxide Semiconductor Field Effect Transistor MosFET

Depletion Mode

$0 \geq V_{GS} > V_P$ سالب

$I_D < I_{DSS}$

$V_{GS} > V_P$ (negative for n-channel)

↑ can be +ve or −ve

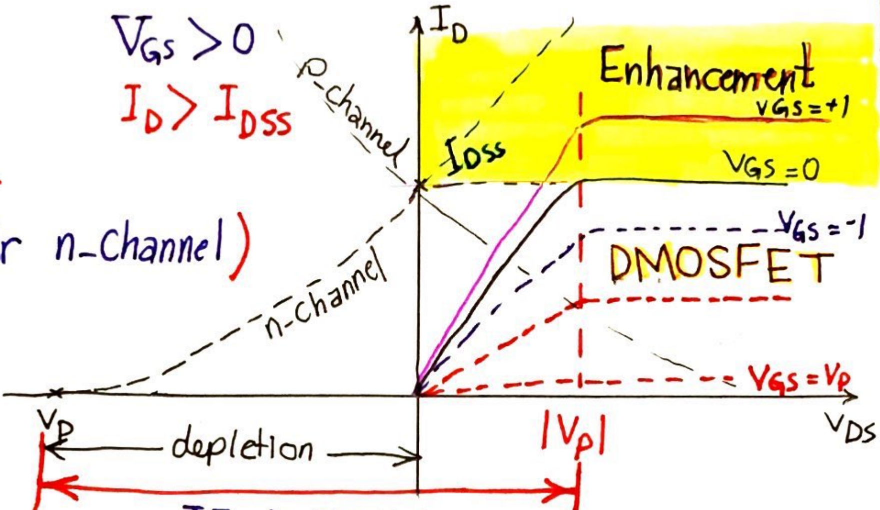
$$I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2$$

$V_P \rightarrow$ سالب

Enhancement Mode

$V_{GS} > 0$

$I_D > I_{DSS}$



$V_{GS} > V$ Enhancement

$I_D < I_{DSS} \Leftarrow$ اذا سالبة // $I_D > I_{DSS} \Leftarrow 0 < V_{GS}$ اذا قيمة

* For the n-channel

$V_{GS} > V_P$ "negative"

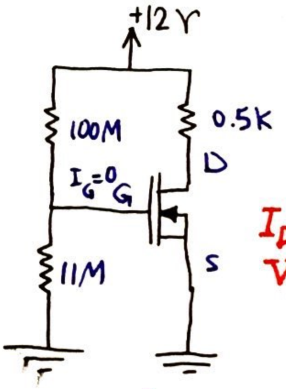
$V_{DS} > V_{GS} - V_P$

* For the P-channel

$V_{GS} < V_P$ "positive"

$V_{DS} < V_{GS} - V_P$

Example



$I_{DSS} = 4mA$

$V_P = -5V$

$$I_{DS} = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2 \quad \ldots \boxed{1}$$

$$V_{GS} = V_G - V_S = V_G$$

$$V_G = \frac{11M}{111M} \times 12 = 1.19V \ldots \boxed{2}$$

$$I_{DS} = I_{DSS}\left(1 - \frac{V_G}{V_P}\right)^2$$

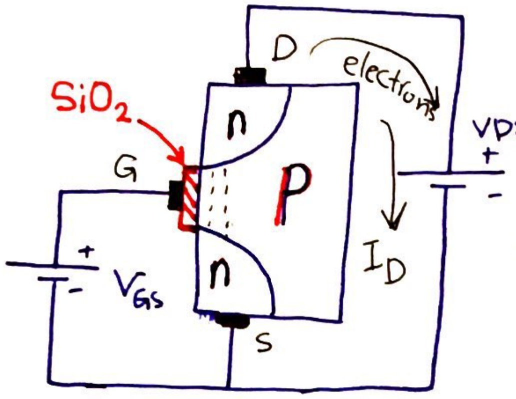
$$I_{DS} = 4mA\left(1 - \frac{1.19}{-5}\right)^2 = 6.13\,mA > I_{DSS}$$!! This is possible AND DMOSFET

∴ Will operate In Enhancement Mode.

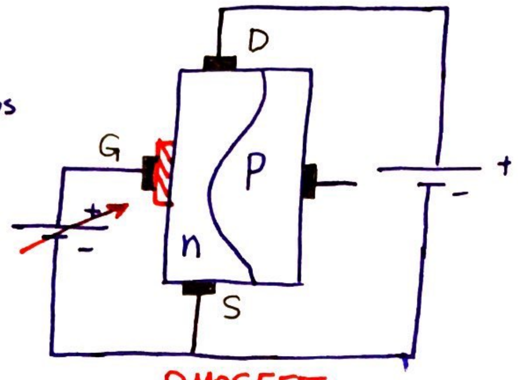
$$V_{DS} = V_{DD} - 0.5K\, I_{DS} = 8.93V$$

$$V_{DS} \overset{?}{>} V_{GS} - V_P = 6.19$$

$$8.93 \overset{?}{>} 1.19 - -5 = 6.19 \checkmark$$

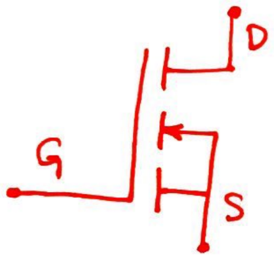


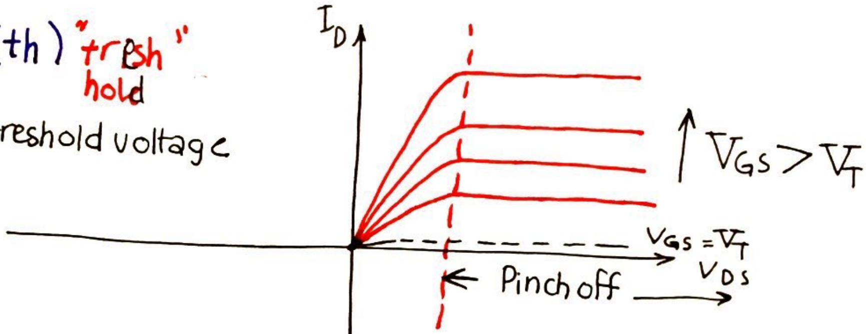
EmosFET
n-channel



DMOSFET

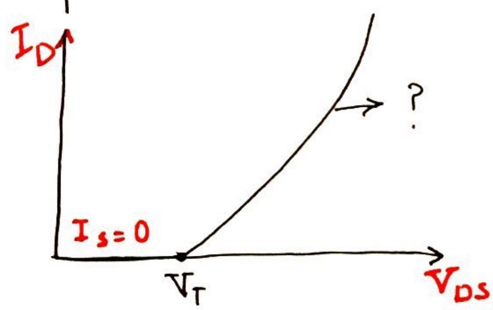
$V_{GS} \geq V_{GS}(th)$ "tresh hold"
V_T treshold voltage





$$I_D = k_n \left(V_{GS} - V_T\right)^2$$

datasheet or calculated



Test point @ $V_{GS} = 5V$
$I_D = 4mA$
$V_T = 3V$

$$\Rightarrow K_n = \frac{I_D}{(V_{GS}-V_T)^2} = \frac{4mA}{(5-3)^2} = 1mA/V^2$$

In the Pinch off Region - EMOSFET

$$i_{DS}(t) = k_n \left(V_{GS}(t) - V_T\right)^2$$

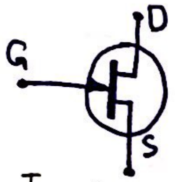
$$|V_{DS}| > |V_{GS} - V_T|$$

$V_{GS} > V_T$ → موجبة   n-Channel
$V_{GS} < V_T$ → سالبة   P-Channel

Electronisc : ENEE236 ⇒ L16 FET ac Analysis

Summary table

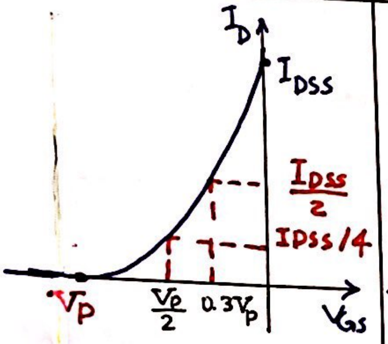
JFET



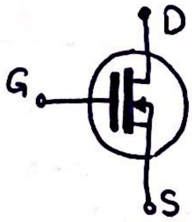
I_{DSS}, V_P

$I_G = 0$, $I_D = I_S$

$I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2$

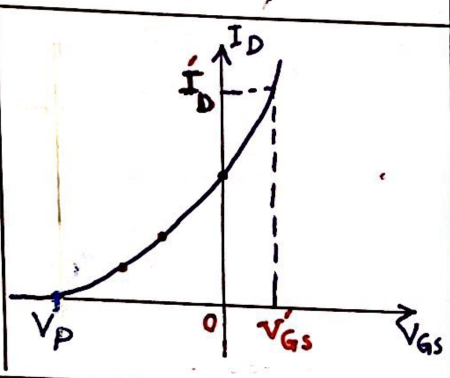


D-MOSFET

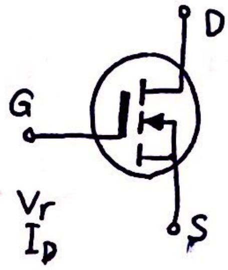


I_{DSS}, V_P

$I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2$



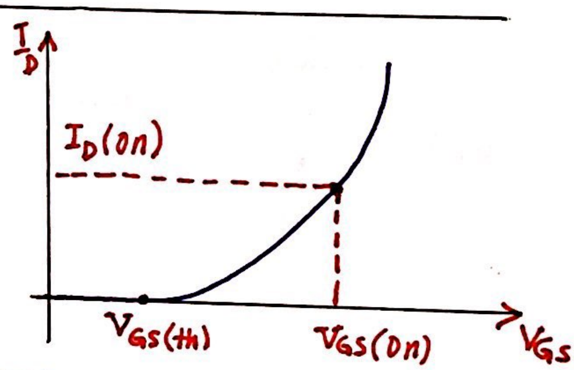
E-MOSFET



V_T, I_D, V_{GS}

$I_D = K\left(V_{GS} - V_{GS(th)}\right)^2$

$k = \frac{I_D}{\left(V_{GS} - V_{GS(Th)}\right)^2}$



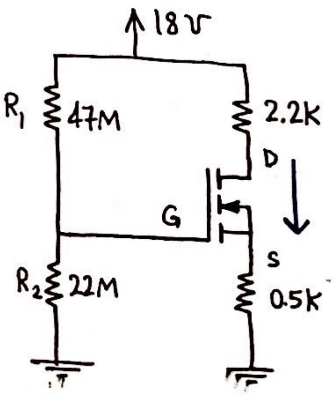
Example

$K_n = 0.25 \times 10^{-3}\ A/V^2$

$V_T = 2V$

لو V_T موجبة معناته n-channel

لو V_T سالبة " P-Channel



$I_{DS} = K_n(V_{GS} - V_T)^2 \ldots$ [1]

$V_{GS} = V_G - V_S$

$V_G = \frac{22M}{22 + 47M} \cdot 18 = 5.74\,V$

$V_S = (0.5K)\,I_{DS}$

$V_{GS} = 5.74 - 0.5K\,I_{DS}$ --- [2]

$V_{GS} = 4.78\,V$ ✓

$= -8.78$ ✗

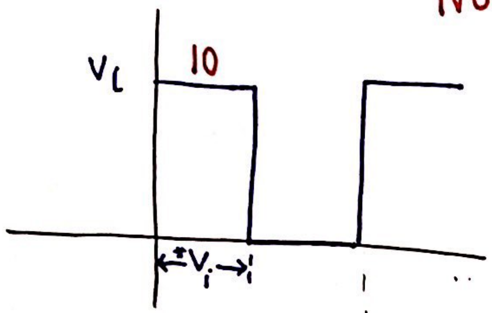
لازم اكبر من V_T

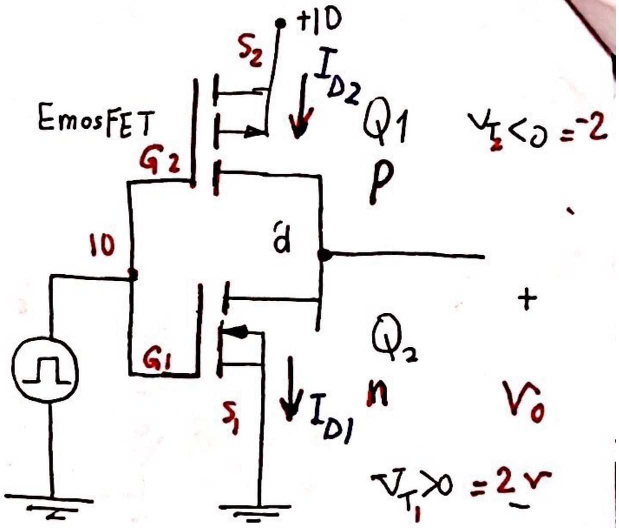
$I_{DS} = 1.92\,mA$

$V_{DS} = 12.82 > |V_{GS} - V_T|$

CMOS Inverter "Complementary MOS"

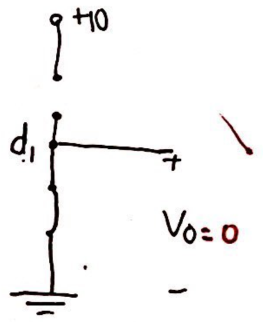
NOT Gate



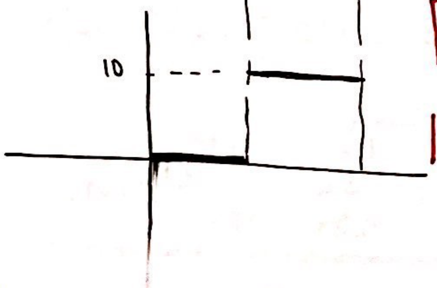


$*V_i = 10 = V_{GS1} > 2 \rightarrow$ عمرر يعني بحط (SC)

$V_{GS2} = 0 > -2 \rightarrow$ ~~ماعرر~~ يعني بحط OC



إذا الانبوت 10 ⇐ الاوتبوت 0

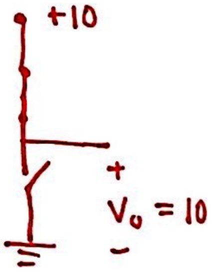


Inverter

[2] $V_i = 0v \Rightarrow V_{GS1} < 2$

Q_1-off

$\rightarrow V_{GS2} = 0 - 10 = -10 < -2$

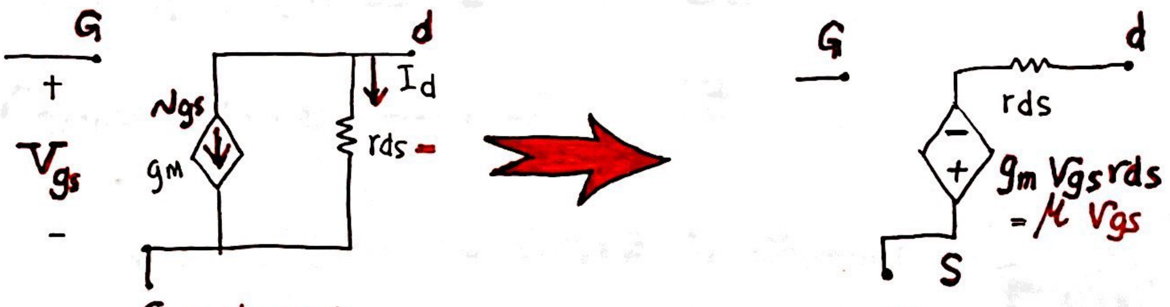


هيك خلصنا لـ L10

L11@NOTES : FET Amplifiers ac small Signal analysis

L16 AS Vidios

For all FET Type



n-channel

$\mu = g_m r_{ds}$

g_m - Transcoductance

Amplification Factor

$$g_m = \frac{\partial I_D}{\partial V_{gs}} \quad \Omega^{-1} \text{ mho} \quad [\text{Always} + \text{ve}] \quad [\text{Siemens}]$$

For JFET & DMOSFET

$$I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2$$

$$\frac{\partial I_D}{\partial V_{gs}} = \frac{2 I_{DSS}}{|V_P|}\left(1 - \frac{V_{GS}}{V_P}\right) = g_{mo}\left(1 - \frac{V_{GS}}{V_P}\right)$$

dc value (V_{GS})

$g_{mo} = g_m\big|_{V_{GS}=0}$

$\left(1 - \frac{V_{GS}}{V_P}\right) \rightarrow \sqrt{\frac{I_D}{I_{DSS}}}$

$$= \frac{2 I_{DSS}}{|V_P|}\sqrt{\frac{I_D}{I_{DSS}}} = \frac{2}{|V_P|}\sqrt{I_D \cdot I_{DSS}}$$

For EMOSFET

$$I_D = K_n (V_{GS} - V_T)^2$$

$$g_m = \frac{\partial I_D}{\partial V_{GS}} = 2K_n (V_{GS} - V_T)$$

$$= 2K_n \sqrt{\frac{I_D}{K_n}} = 2\sqrt{I_D K_n}$$

$K_n = \frac{I_D}{(V_{GS} - V_T)^2}$ @ the Q-point "dc value"

..3.

FET Amplifier

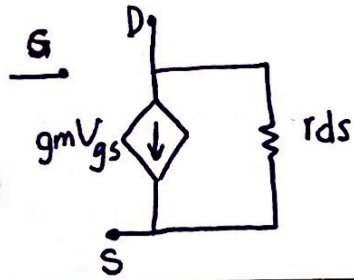
Common Sourse → eq. to CE "Input Gate, Output Drain"

Common Drain → eq. to CC

Common Gate → eq. to CB

all have the same eq. Circuit "n-channel"

For P-channel → current from S to D "↑"

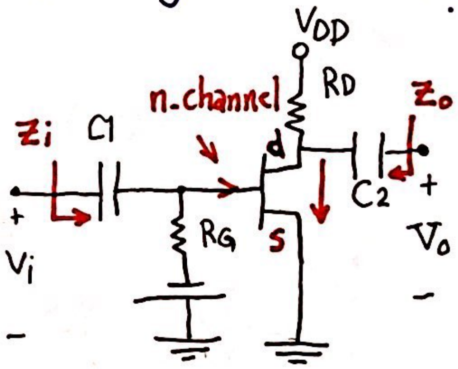


[1] Common Source Amplifier with self Bias "Inverting"

Yup!

Find A_v, Z_i, Z_o
↓
ac ss quantities → Construct ac eq. Circuit

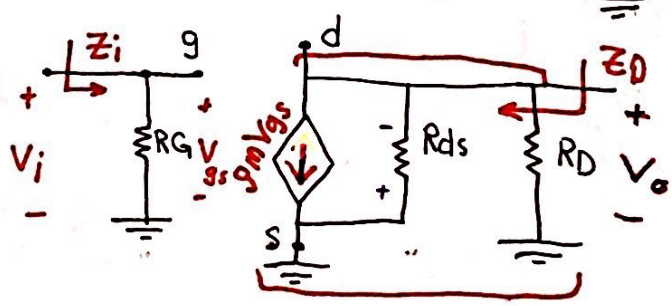
- C_1, C_2 "Short"
- $V_{DD} = 0$ (GND)
- JFET ac ss. Model



- $Z_i = R_G$
- $Z_o \downarrow = R_D // r_{ds}$ (كبيرة كثير)
  $V_i = 0$ — لهيك مرات تكون تساوي ال RD

For this $r_{ds} \gg R_D$

$\therefore Z_o = R_D$



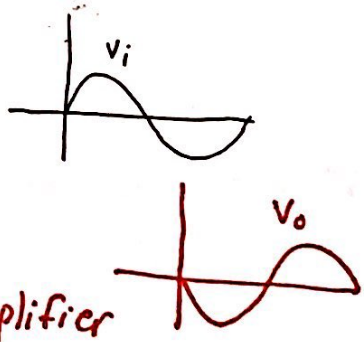
Rds, RD → Shared Ground & shared Drain

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

$$\begin{cases} V_o = V_{ds} = -g_m V_{gs} (r_{ds} // R_D) \\ V_i = V_{gs} \end{cases}$$

$$A_v = \frac{-g_m V_{gs} (r_{ds} // R_D)}{V_{gs}} = -g_m (r_{ds} // R_D)$$

$$= -g_m (R_D)$$



Inverting Amplifier
Vo is shifted 180° relative to Vi

Common Source (Self Bias)

$(r_{ds} \cong \infty)$

$V_{gs} \neq V_i$

$V_{gs} = V_g - V_s$

$V_{gs} = V_i - g_m V_{gs} R_s \Rightarrow V_{gs} = \frac{V_i}{1 + g_m R_s}$

$A_V = \frac{V_o}{V_i}$;

$V_o = -g_m V_{gs} R_D$

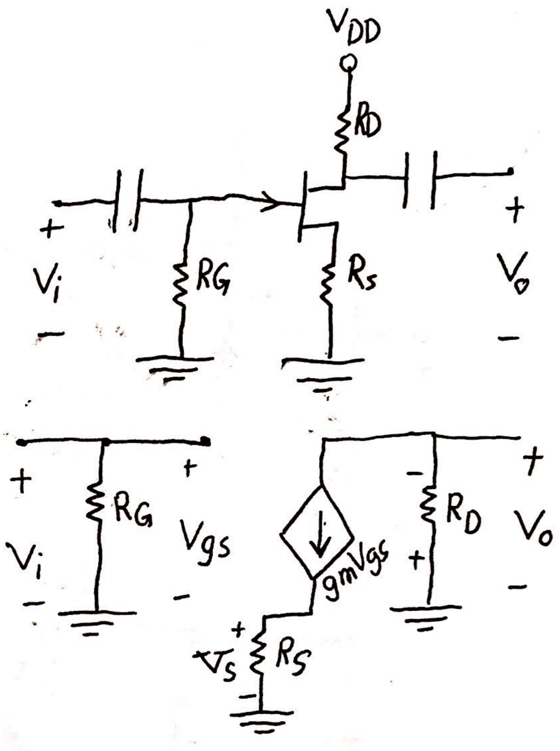
$V_{gs} = V_g - V_s$

$= V_i - \ldots$

$A_V = \frac{-g_m R_D}{1 + g_m R_s}$;

اكبر المقام ← $1 + g_m R_s$

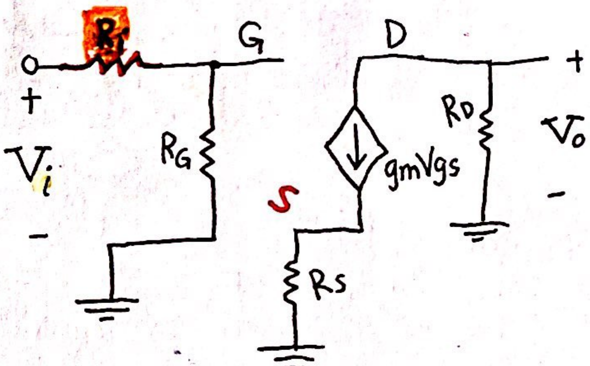
Av is ↓ due to Rs



Scanned with CamScanner

L16 : Part 2 : FET ac analysis ⇨

Common Sourse (CS) Self Bias Effect of Ri



here $V_g = \frac{R_G}{R_G + R_i} \cdot V_i$

$V_{gs} = V_g - V_s$

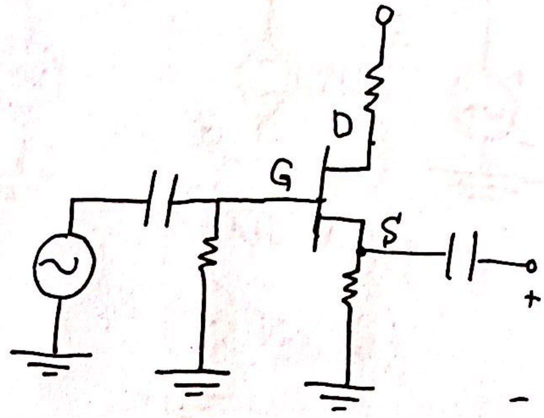
$V_{gs} = \frac{R_G}{R_G + R_i} \cdot V_i - g_m V_{gs} R_s$

$V_i = V_{gs}(1 + g_m R_s) \frac{R_G + R_i}{R_G}$

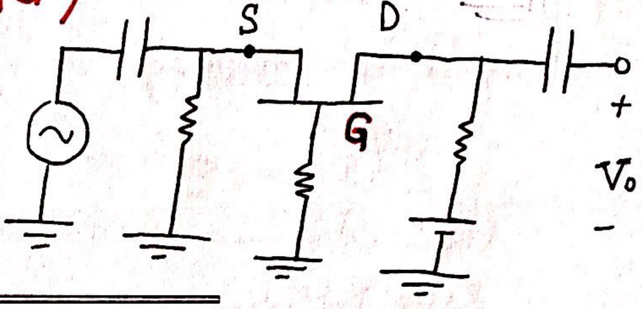
$V_o = -g_m V_{gs} R_D$

$A_V = \frac{V_o}{V_i} = \frac{-g_m R_D}{1 + g_m R_s} \cdot \boxed{\frac{R_G}{R_G + R_i}}$ AV is reduced Further due to Ri

2 Common drain (CD)



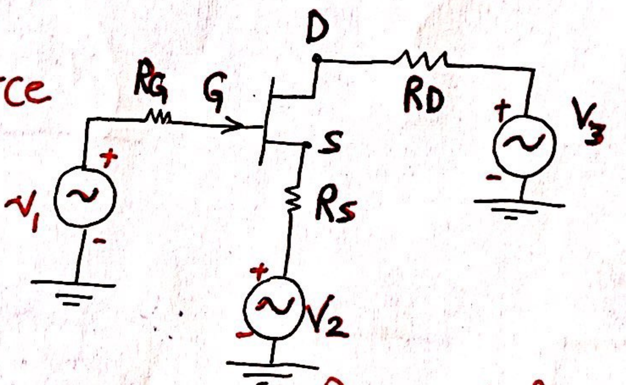
3 Common Gate (CG)

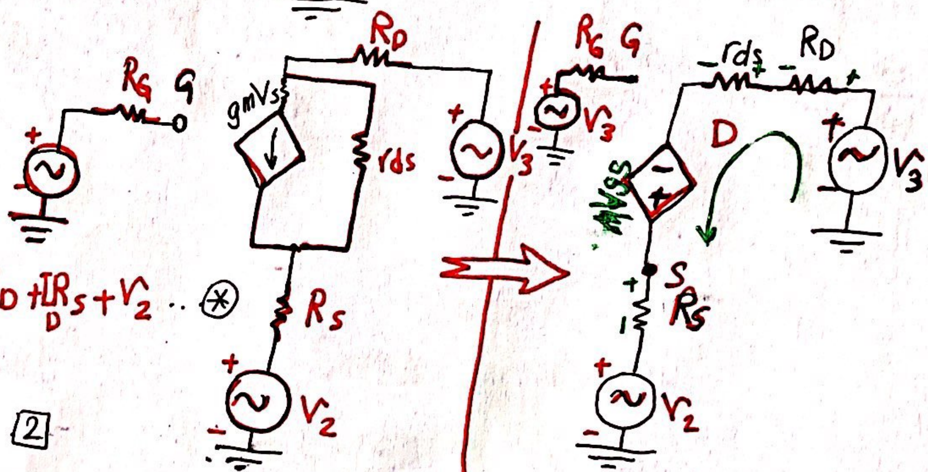


Impedence Reflection

Drain ⟷ Source

Rs





KVL :

$V_3 + \mu V_{gs} = I_D r_{ds} + I_D R_D + I_D R_S + V_2$ .. (*)

$V_{gs} = V_g - V_s$ ... [1]

$= V_g - (i_D R_S + V_2)$ .. [2]

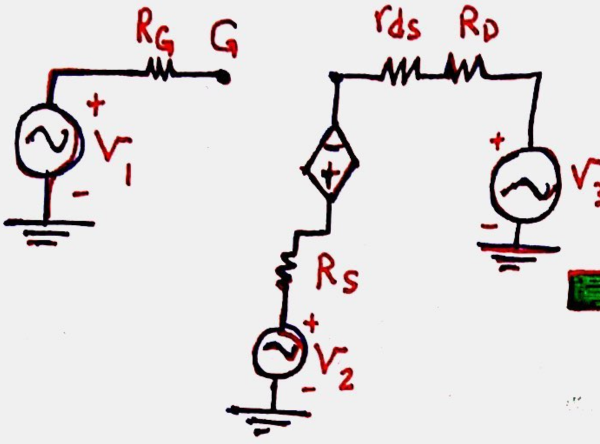
$V_s = I_D R_S + V_2$ ... → at [1]

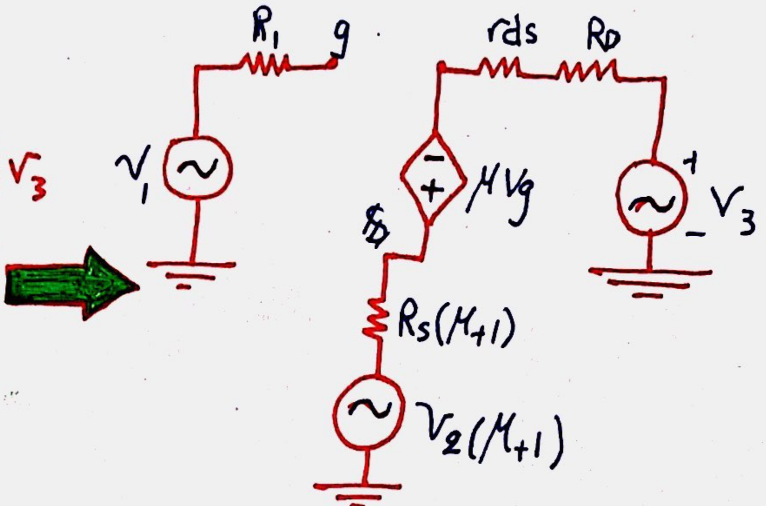
نعوض [2] في (*)

$V_3 + \mu(V_g - (i_D R_S + V_2)) = I_D(r_{ds} + R_D + R_S)$

$$i_D = \frac{V_3 + \mu V_g - V_2(\mu+1)}{R_D + r_{ds} + R_S(\mu+1)}$$

$$i = \frac{\Delta V}{\Sigma R}$$





Original Circuit

Drain Equ. Circuit

(Source to Drain)

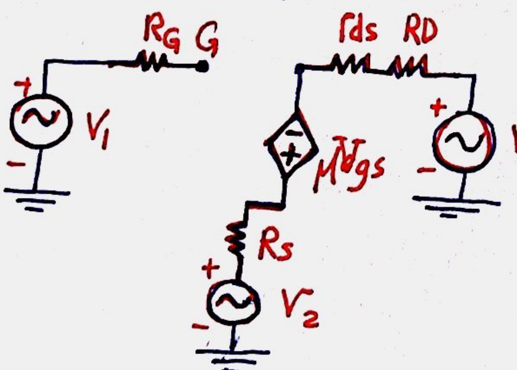
$\mu v_{gs} \longrightarrow \mu v_g$

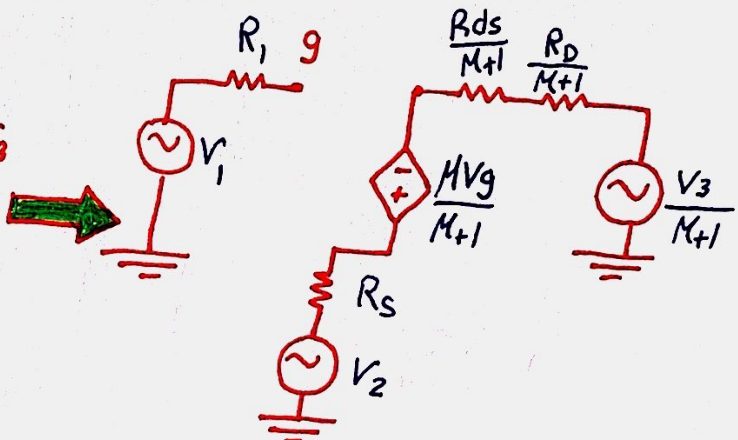
$R_s \longrightarrow R_s(\mu+1)$

$V_2 \longrightarrow V_2(\mu+1)$

تعويض على $\mu+1$

$$i_D = \frac{\frac{V_3}{\mu+1} + \frac{\mu V_g}{\mu+1} + -V_2}{\frac{R_D}{\mu+1} + \frac{r_{ds}}{\mu+1} + R_s}$$





Original circuit

Source Eq. Circuit

(Drain to Source)

$\mu V_{gs} \longrightarrow \frac{\mu V_g}{\mu+1}$ $\quad R_D \rightarrow \frac{R_D}{\mu+1}$

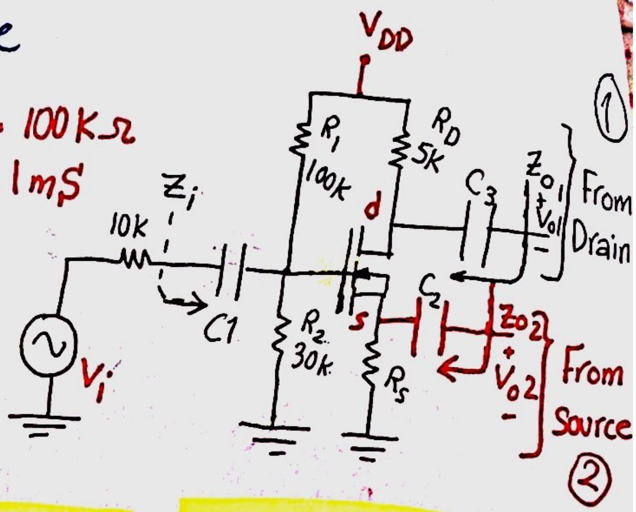
$V_3 \longrightarrow \frac{V_3}{\mu+1}$ $\quad R_{ds} \rightarrow \frac{R_{ds}}{\mu+1}$

Example : Phase splitting Circuit

Two outputs : treated one @ time

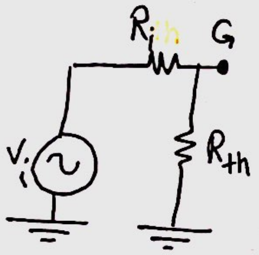
Find $A_{V_1}, A_{V_2}, Z_i, Z_{o_1}, Z_{o_2}$

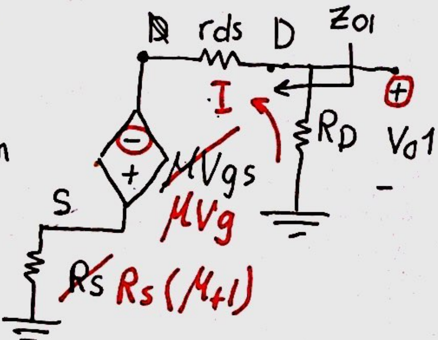
$r_{ds} = 100k\Omega$
$g_m = 1mS$



Two outputs :
Vo1 : Drain
Vo2 : Source .

①





(D تحول لل) From S to D

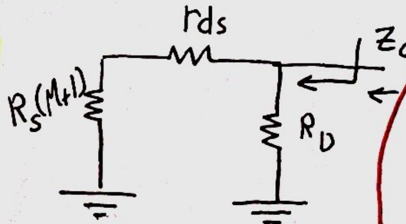
$$V_{o1} = \frac{R_D}{R_D + r_{ds} + R_s(\mu+1)} \cdot (-\mu V_g)$$

$$V_g = \frac{R_{th}}{R_{th} + R_i} \cdot V_i$$

$$A_{V_1} = \frac{V_{o1}}{V_g} \cdot \frac{V_g}{V_i} = \checkmark$$

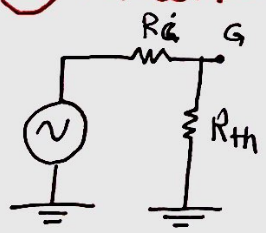
$$Z_{o1} = R_D \,//\, (r_{ds} + R_s(\mu+1))$$

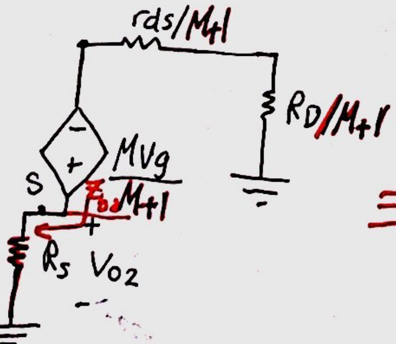
$V_i = 0 \Rightarrow V_g = 0 \Rightarrow \mu V_g = 0$

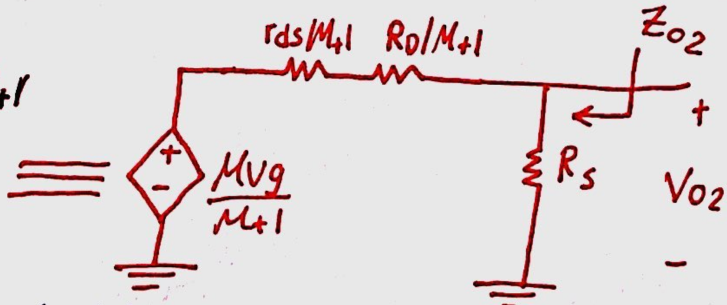


$$Z_i = R_{th}$$

② reflection from Drain to Source







$$V_{o2} = \frac{R_s}{R_s + \frac{r_{ds} + R_D}{\mu + 1}} \cdot \frac{\mu V_g}{\mu + 1}$$

من السابق

$$V_g = \frac{R_{th}}{R_{th} + R_i} \cdot V_i$$

$$Z_{o2} = R_s \,//\, \left(\frac{r_{ds} + R_D}{\mu + 1}\right)$$

$V_i = 0 \Rightarrow V_g = 0$

.8. Back $\Rightarrow$ "فرضا" $r_{ds} \rightarrow \infty$

Scanned with CamScanner

$$\mu = g_m r_{ds}$$

$$Z_{o_2} = R_S \parallel \left(\frac{r_{ds} + R_D}{(\mu + 1)} \right) \quad (r_{ds} \to \infty)$$

$$\left. \frac{r_{ds} + R_D}{\mu + 1} \right|_{r_{ds} \to \infty} = \frac{r_{ds} + R_D}{g_m r_{ds} + 1}$$

$$\lim \frac{1 + \cancel{R_D / r_{ds}}^{\,0}}{g_m + \cancel{1 / r_{ds}}^{\,0}} = \frac{1}{g_m}$$

$$\left. Z_{o_2} \right|_{r_{ds} \to \infty} = \left. R_S \parallel \frac{1}{g_m} \right|_{r_{ds} \to \infty}$$

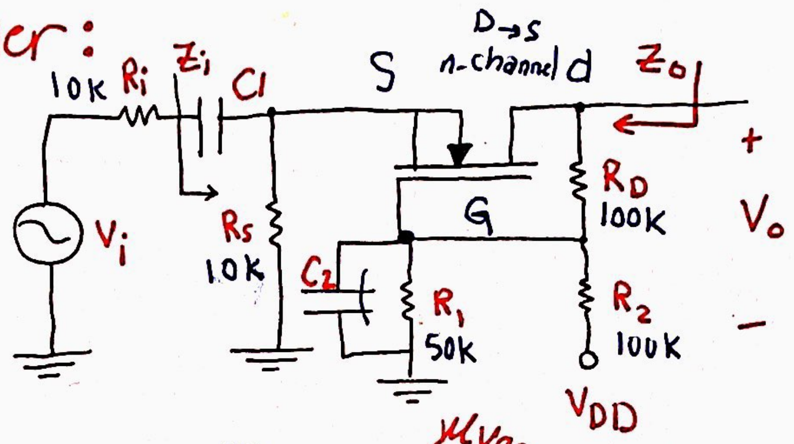
Electronics : ENEE236 → L17 FET Design

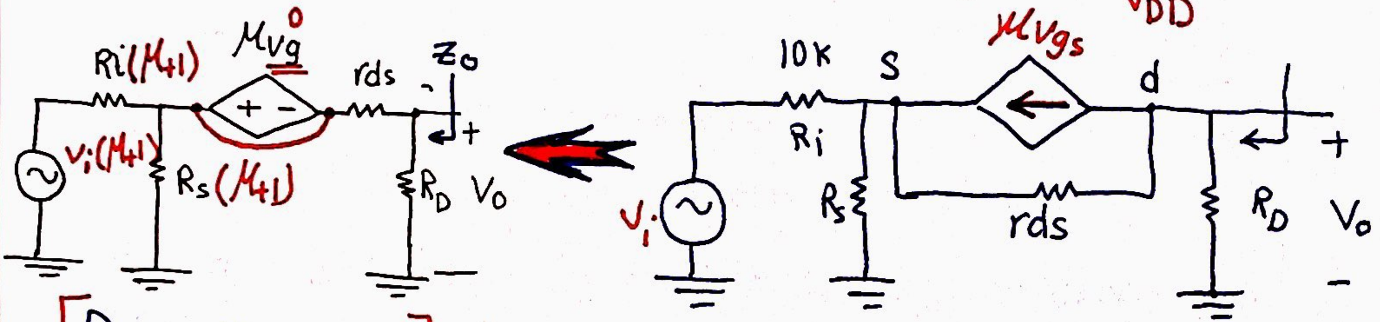
Comon Gate Amplifier :

Z_i, Z_o, A_v

Short "C"

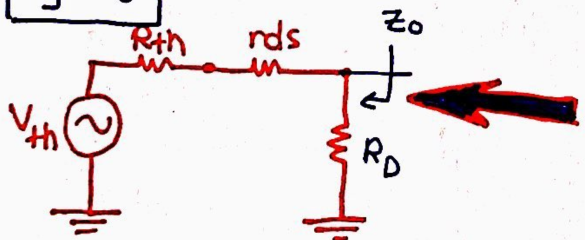
$V_{DD} \rightarrow$ ⏚

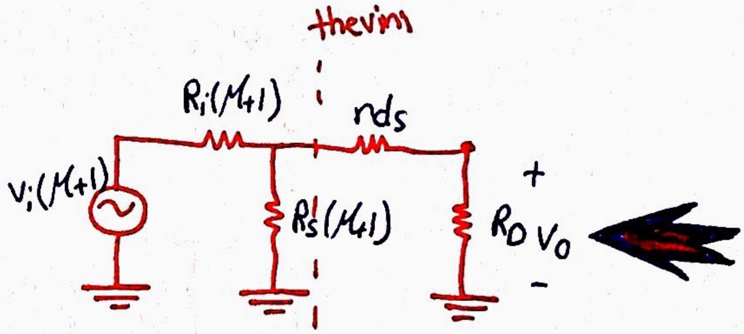




[Drain Eq. Circuit]

$V_g = 0$





" Special case "

$R_{th} = 5K(\mu+1)$

$= R_i(\mu+1)/2$

, $V_{th} = \frac{1}{2} V_i (\mu+1)$ لانو $R_s = R_i$ في الجهد عليها بنقسم للنص في كل وحدة بتوخذ $\frac{(\mu+1) V_i}{2}$

$$V_o = \frac{R_D}{R_D + rds + R_{th}} \cdot V_{th}$$

$$V_o = \frac{R_D}{R_D + rds + R_{th}} \cdot \frac{(\mu+1) V_i}{2}$$

$$\therefore A_V = \frac{R_D(\mu+1)}{2\left[R_D + rds + \frac{R_i(\mu+1)}{2}\right]}$$

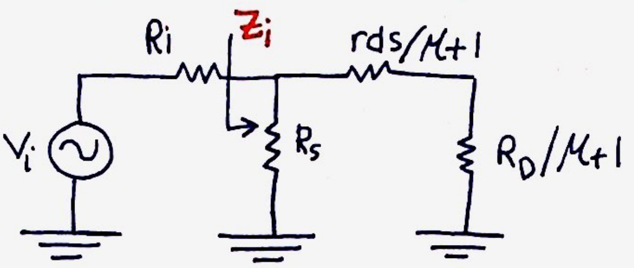
$$Z_o \Big| = R_D \,//\, (R_{th} + rds)$$

$V_{th} = 0$

$$= R_D \,//\, \left(rds + \frac{5K(\mu+1)}{2}\right)$$

when $rds \approx \infty$ $Z_o = R_D$

to Find $Z_i \rightarrow$ Source Eq. is needed



$$Z_i = R_S // \left(\frac{r_{ds} + R_D}{\mu + 1} \right)$$

$$Z_i \Big|_{r_{ds} \rightarrow \infty} = R_S // \frac{1}{g_m}$$

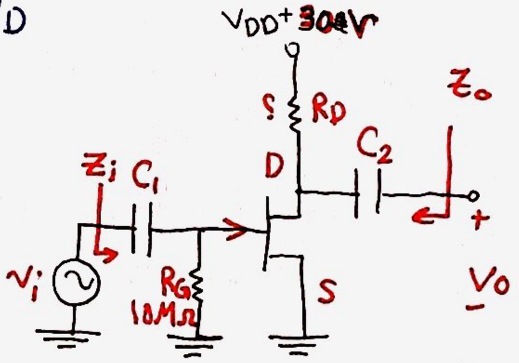
FET Amplifier Design "Important"

- Design a fixed Bias network such that the ac voltage gain $|A_V| = 10$, i.e. find value of R_D

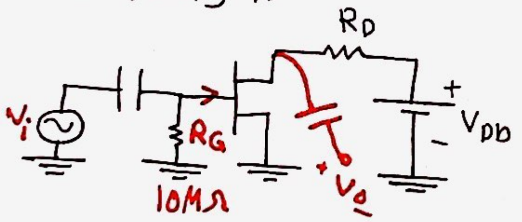
$V_P = -4V$

$I_{DSS} = 10mA$

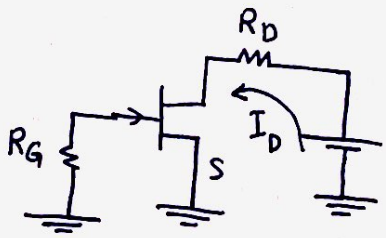
$r_{ds} = 50K\Omega$



After Analysis



$\Rightarrow$



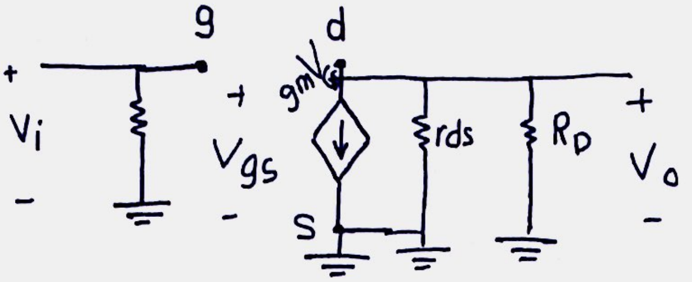
$V_{GS} = V_G - V_S$ "DC Analysis"

$= 0 - 0 = 0$

$$I_D = I_{DSS} \left(1 - \frac{V_{GS}}{V_P}\right)^2$$

$= 10mA$

$$g_m = \frac{2 I_{DSS}}{|V_P|} \left(1 - \frac{\overset{0}{V_{GS}}}{V_P}\right) = \frac{2 \times 10mA}{4} = 5m\mho$$



Ac Analysis

$V_o = -V_{gs} g_m (R_D // r_{ds})$

$V_{gs} = V_i$

$|A_v| = \frac{V_o}{V_i} = |-g_m (R_D // r_{ds})| = 10$

$r_{ds} // R_d = \frac{10}{5m} = 2K\Omega$

$\frac{r_{ds} \times R_d}{r_{ds} + R_d} = 2k$ (with r_{ds} = 50) $\Rightarrow$ **$R_D = 2.08\ K\Omega$**

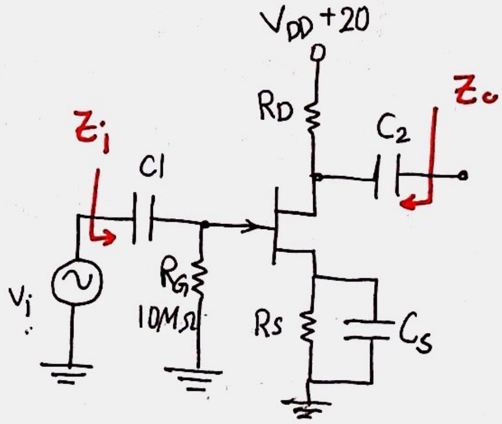
Design Example 2 "Important"

Choose the value of R_D & R_S that will result in voltage gain $|A_v| = 8$, Using the value of g_m defind by $V_{GSQ} = \frac{1}{4} V_p$

$V_p = -4 \Rightarrow V_{GSQ} = -1$

$I_{DSS} = 10mA$

$r_{ds} = 50K$



at dc → C → "open"
at AC → C → short

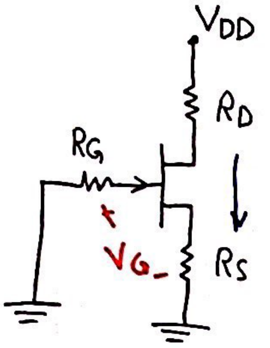
زي اللي مرقت بال A.C.A

$|A_v| = |-g_m (R_D // r_{ds})|$

$g_m = \frac{2 \times 10mA}{4} \left(1 - \frac{-1}{-4}\right) = 5mS \times 0.75 = 3.75\ S$

$\frac{8}{3.75} = \frac{R_D \times 50k}{50K + R_D} \Rightarrow R_d = 2.133k\Omega$

DC Analysis



$V_{GSQ} = \frac{1}{4} V_P = -1$

$= \cancel{V_G} - V_S$ ($V_G = 0$, $V_S \to I_D R_S$)

$-1 = -I_D R_S$

$1 = I_D R_S \Rightarrow R_S = \frac{1}{5.625m} = \cancel{1.77}\ 177.7\,\Omega$

Use Standard Value! $180\,\Omega$

$I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2$

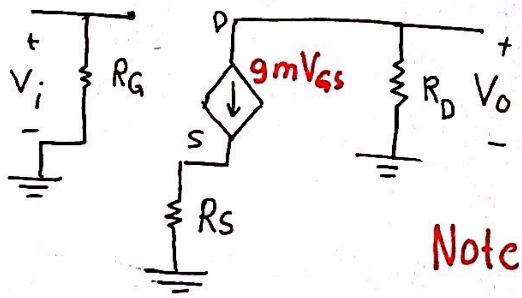
$= 10mA\left(1 - \frac{1}{4}\right)^2 = 5.625\,mA$

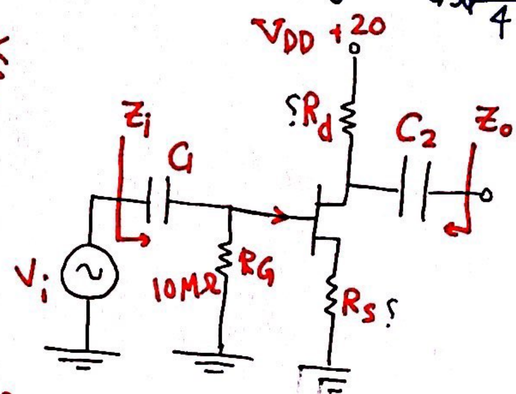
Design Example 3

Choose the value of R_D & R_S that will result in $|A_V| = 8$, using the value of g_m def. by : $V_{GSQ} = \frac{1}{4} V_P$

$V_P = -4$, $V_{GSQ} = -1$, $I_{DSS} = 10mA$, $r_{ds} = \cancel{50K}\ \infty$

AC SS Eq. Circuit :





Note: This the same Previous Ex. except that no Cs Cap.

$g_m = 3.75$ (from Previous Ex)

$A_V = \frac{V_o}{V_i}$

$V_o = -g_m V_{GS}(R_D \parallel r_{ds})$

$V_{GS} = V_G - V_S = V_G - g_m V_{gs} R_s$

$V_g = V_i \Rightarrow V_{gs} = V_i - g_m V_{gs} R_s$

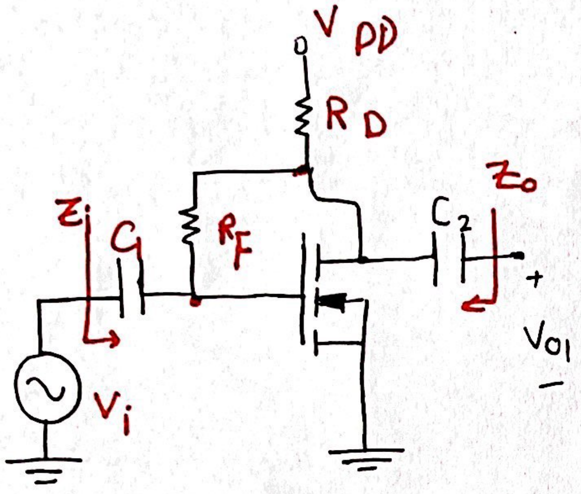
$V_i = V_{gs} - g_m V_{gs} R_s$

$V_o = \frac{-g_m V_{gs}(R_D)}{V_{GS} + g_m V_{gs} R_s} = \frac{-g_m R_D}{1 + g_m R_S}$

$|A_V| = \left|\frac{-g_m R_D}{1 + g_m R_S}\right| = 8 \Rightarrow R_S = 177.7 \approx 180$

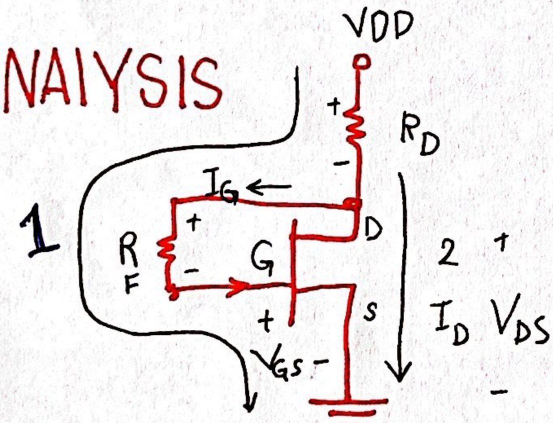
$R_D = 3.573\,k\Omega$

Drain Feedback Configaration



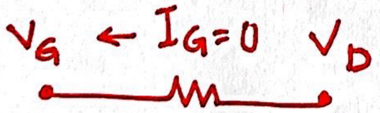
Just DC Analysis

DC ANAlYSIS



① $V_{DD} = I_D R_D + \cancel{I_G}^{0} R_F + V_{GS} \ldots \longrightarrow V_{GS} = V_{DD} - I_D R_D$

② $V_{DD} = I_D R_D + V_{DS} \longrightarrow V_{DS} = V_{DD} - I_D R_D$



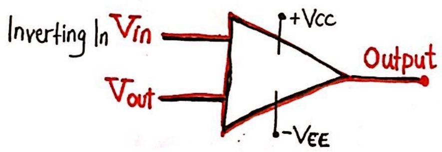
$V_D = V_G$

$V_{DS} = V_{GS}$

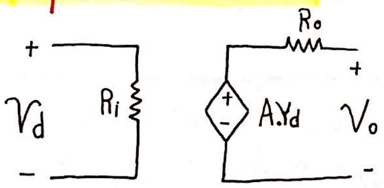
Electronics 236 → L18 Part1 op-amp1

- Operational Amplifier
  - Integrated Circuit.
  - Used for different Applications
    - Math operations
    - Comparison
    - Filters
    - Communications Eng.
    - Control systems
    - Instrumentation

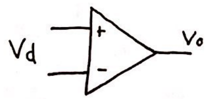
OP_ Amp "Not design but how to use the op amp as a device.



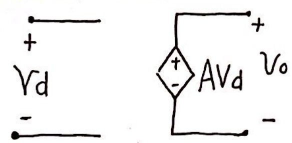
Equivalent Circuit:



- A very high (A > 100000)
- R_i very high (MΩ's)
- R_o very small (Ω's)



Ideal op-amp: "Equivalent Circuit" Considering ↑↑ R_i "open Circuit" and ↓↓ R_o "Short Circuit"

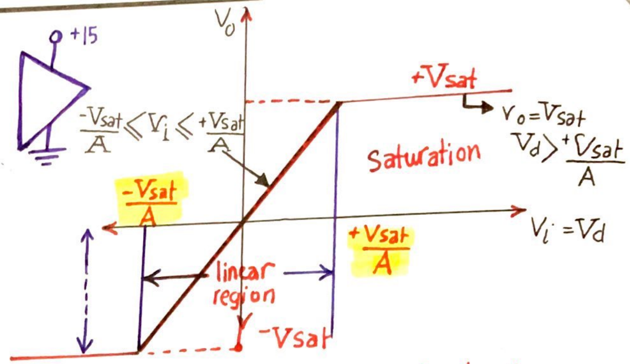


Op-amp characteristic

$^{+}V_{sat} \cong {}^{+}V_{cc} - 2$

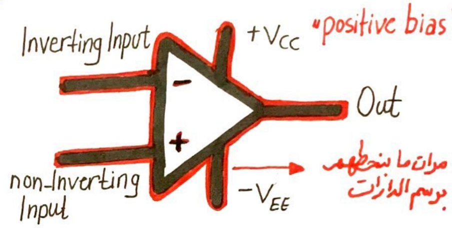
$^{-}V_{sat} \cong {}^{-}V_{cc} + 2$

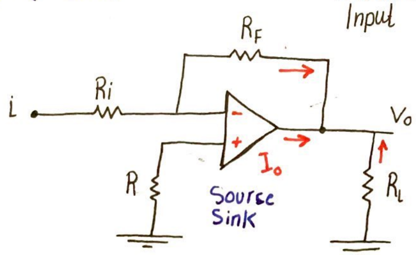
"For Calculation Parpos" in this Course

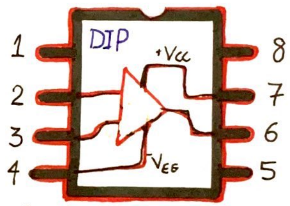


Op-Amp Ratings

1. $^{-}V_{sat} \leqslant V_o \leqslant {}^{+}V_{sat}$
2. $I_o \leqslant I_{o\,max}$

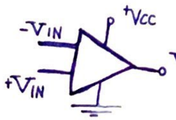




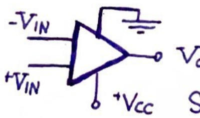


Dual in-ling Pack

Most OP Amps require dual power supply with Common Ground
& Some Op Amps require single Supply "with some restriction"

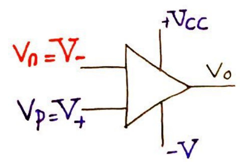


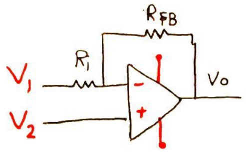
Single Positive Voltage

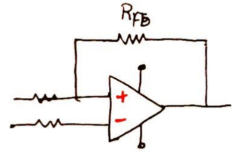


Single negative Voltage

OP-Amp Configuration







① no feedback
- used as Comparator

$V_o = \pm V_{sat}$

② Negative feedback
- used as an Amplifier

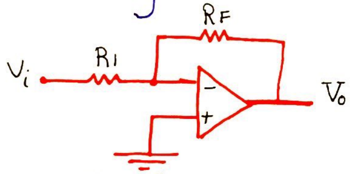
$-V_{sat} < V_o < +V_{sat}$

③ Positive feedback
- Comparator with Hyst.

$V_o = \mp V_{sat}$

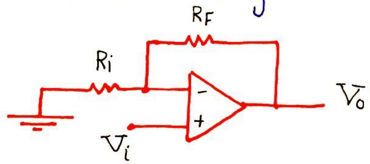
Op-Amp as an Amplifier

Inverting



$$V_o = \frac{-R_F}{R_i} V_i$$

Non-Inverting



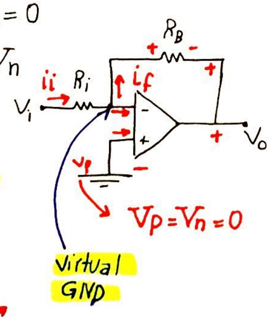
$$V_o = \left(1 + \frac{R_F}{R_i}\right) V_i$$

L18_Part 2 Inverting Amp. Analysis

Using ideal op-amp Model

$$\begin{cases} i_p = i_n = 0 \\ V_p = V_n \end{cases}$$

only for Amp. with negative feedback

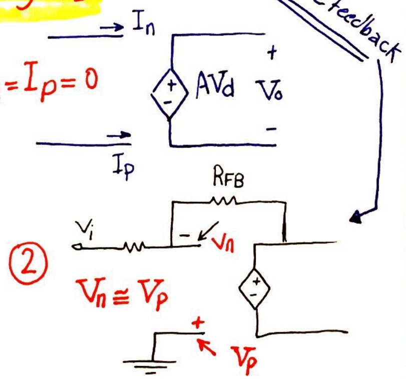


$$i_i = i_f + i_n^{\,0}$$

$$i_i = \frac{V_i - V_n^{\,0}}{R_i} = \frac{V_i}{R_i} = i_f$$

① $I_n = I_p = 0$

Negative feedback



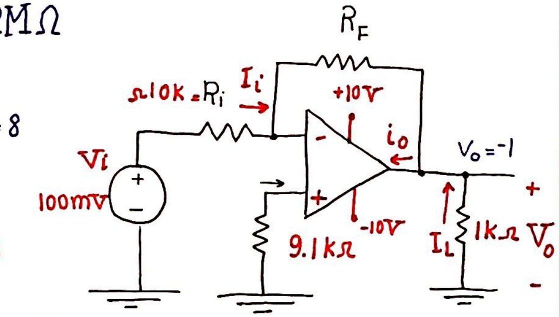
② $V_n \cong V_p$

$$V_o = -i_f R_F = \frac{-V_i}{R_i} \cdot R_F = \frac{-R_F}{R_i} V_i$$

Example

Find the value of V_o and I_o and verify if the opamp is in linear or saturation mode for two values of feedback resistor; assume $I_{o(max)} = 20\,mA$

[1] $R_f = 100\,k\Omega$ [2] If $R_F = 2M\Omega$



$-10+2=-8$ $\quad V_p = 0 \quad$ $10-2=8$

$$-V_{sat} \leqslant V_o = \frac{-R_F}{R_i} \cdot V_i \leqslant +V_{sat}$$

$$I_o \leqslant I_{o(max)} = 25\,mA$$

$$V_o = \frac{-100K}{10K} \cdot V_i = -10 \times 100mV = -1$$ ضمن الرينج

$$i_i = i_f = \frac{100\,mV}{10\,K} = 10\,\mu A$$

$$i_L = \frac{1}{1K} = 1mA$$

$$i_o = i_f + i_L = 10\mu A + 1mA$$
$$= 1.01\,mA < 20\,mA \checkmark$$

op Amp is a low current device

---

[2] $R_F = 2M\Omega$ $\Rightarrow 2000\,k$

$$V_o = \frac{-2M}{10K} * 100\,mV$$
$$= -20\,V$$

, $-V_{sat} \leqslant V_o \leqslant +V_{sat}$, but V_o not in the range

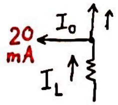
V_o is Limited to $-8V$

$$I_o = 10\mu + \frac{8}{1K} = 8\,mA \checkmark$$

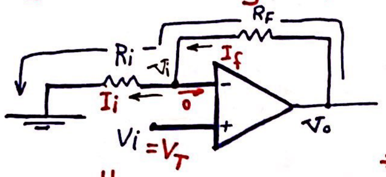
Assume $R_L = 200\Omega$

$$I_o = 10\mu + \frac{8}{200} = 40.01\,mA > I_{o(max)}$$, I_o is limited to 20mA

$$V_o = -20mA \times 200 = -4V$$



Non-Inverting Amp.

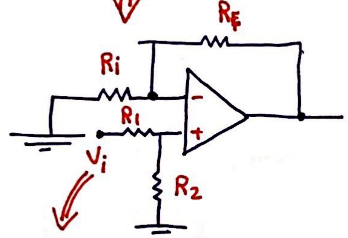


$I_p = I_n = 0$

$V_p = V_n = V_+ = V_-$

$\rightarrow i_i = \frac{V_i}{R_i}$

$\rightarrow i_f = i_i + i_n$ (→ 0)



$V_+ = \frac{R_2}{R_1 + R_2} \cdot V_i$

$V_o = I_f R_F + I_i R_i$

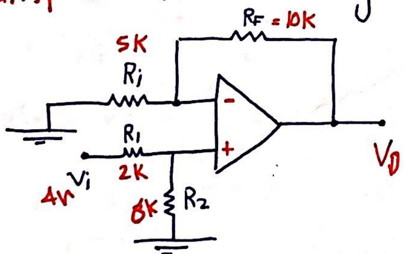
$V_o = I_f (R_F + R_i)$

$= \frac{V_i}{R_i}(R_F + R_i)$

$$V_o = V_i\left(1 + \frac{R_F}{R_i}\right)$$

, general case V_+ Instead of V_i

Example "Non-inverting"



$V_o = V_+\left(1 + \frac{R_F}{R_i}\right)$

$= 3\left(1 + \frac{10K}{5K}\right) = 9$ volt

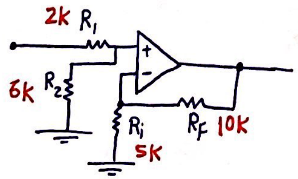
$-V_{sat} \leq V_o \leq +V_{sat}$

$V_+ = \frac{6K}{8K} \cdot 4 = 3$

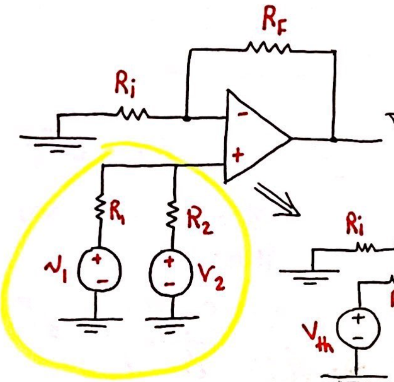
$1 = \frac{V_o}{V_+}$ لنفرض حدا طلب ال Gain=1 يعني
الحل انو يا بخلي R_F short و open R_i

⇘ Buffer اسمها

* الدارة هاي نفس اللي فوق



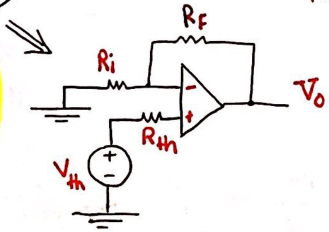
Non-Inverting Adder



$R_1 = R_2 = R_F = R_i = R$

$V_o = \left(1 + \frac{R_F}{R_i}\right) \cdot V_+$

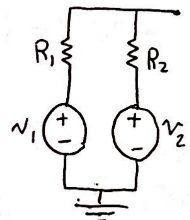
From [1]



$V_o = (2) \cdot \left(\frac{1}{2}(V_1 + V_2)\right)$

$$V_o = V_1 + V_2$$

Super Position :



[1] Kill V_2

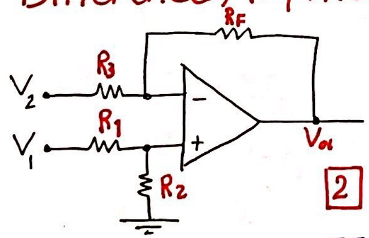
$V'_{th} = \frac{R}{R+R} V_1 = \frac{1}{2} V_1$

[2] Kill V_1

$V''_{th} = \frac{R}{2R} \cdot V_2 = \frac{1}{2} V_2$

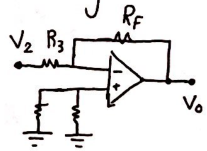
[3] $Total = V'_{th} + V''_{th} = \frac{1}{2}(V_1 + V_2) \ldots$ [1]

Difference Amplifier - mix of Inverting & non-Inverting



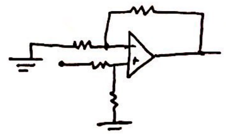
[1] Kill V_1 ⇒ Inverting

$V_o = \frac{-R_F}{R_3} V_2$



[2] Kill V_2 ⇒ Non-Inverting

$V_o = \left(1 + \frac{R_F}{R_3}\right) V_+ \quad , \quad V_+ = \frac{R_2}{R_1 + R_2} \cdot V_1$



Difference Amplifier Continue

$$V_o = \underbrace{\left(1+\frac{R_F}{R_3}\right)\left(\frac{R_2}{R_1+R_2}\right)}_{a} V_1 - \underbrace{\frac{R_F}{R_3}}_{b} V_2$$

$$V_o = aV_1 - bV_2$$

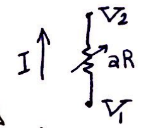
let $R_1 = R_3 = R$
$R_2 = R_F = mR$

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

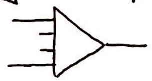
$$= \frac{R_2}{R_3}V_1 - \frac{R_F}{R_3}V_2 = mV_1 - mV_2 = m(V_1 - V_2) \cdots \circledast$$

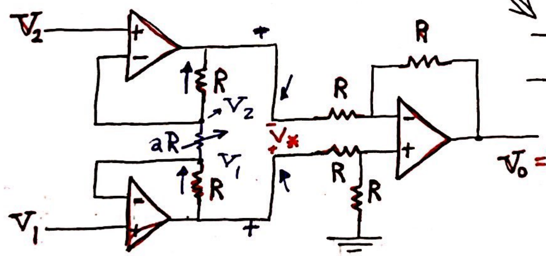
Difference Amplifier

Instrumentation Amp (IC)

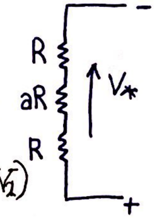


$$I = \frac{V_1 - V_2}{aR}$$





$V_o = V_* = V_{1*} - V_{2*}$



$V_* = I \cdot (2R + R_a) \Leftarrow$

$= \frac{(a+2)R}{aR}(V_1 - V_2)$

$V_* = \left(1+\frac{2}{a}\right)(V_1 - V_2) \cdots$ [1]

From [1] : $V_o = V_*$

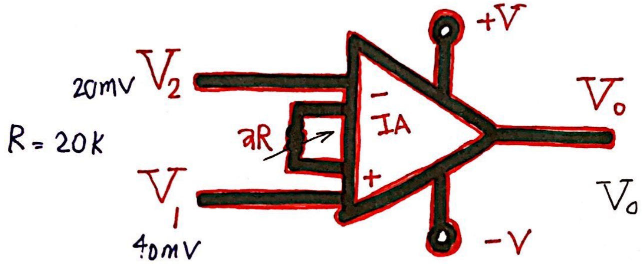
$V_o = \left(1+\frac{2}{a}\right)(V_1 - V_2)$

$m\ (V_1 - V_2)\circledast$ هي نفسها

$m = 1 + \frac{2}{a}$ يعني

هنا يعني Only changeng potentiometer value, Gain is adjested + Buffers

يعني لما بدي اغير بال Gain بس يعني بغير بقيمة a في المقاومة المتغيرة .



$V_o = \left(1+\frac{2}{a}\right)(V_1 - V_2)$

5 = Gain بنا ال

$5 = \left(1 + \frac{2}{a}\right)(40m - 20m)$

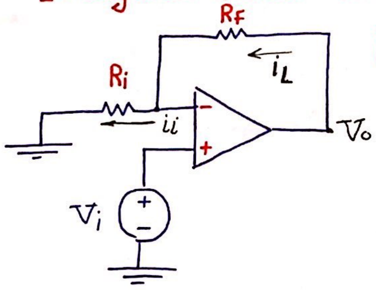
$250 = 1 + \frac{2}{a} \Rightarrow a = \frac{2}{240}$

$aR = \frac{2}{240} \times 20K =$

$\frac{1}{2}(V_1 + V_2)$

Electronics : 236 → L20 Op Amps Apps

Voltage to Current Converter :



$i_i = \frac{V_i}{R_i}$

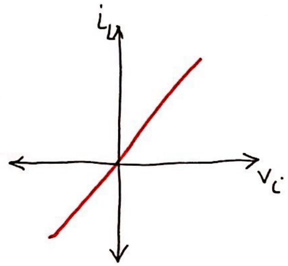
$i_i = i_L$

Let $V_i = 1V$, $R_i = 1K$

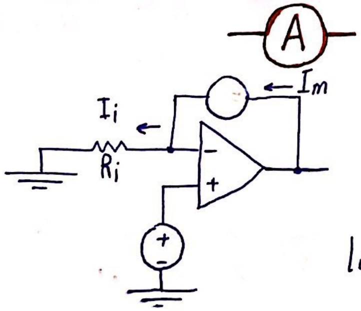
$i_L = \frac{1V}{1K} = 1mA$

let $V_i = -1V$

$i_L = -1mA$



V to I Converter → Replace R_L by a PMMC



Ammeter ← (Galvanometter)

↓

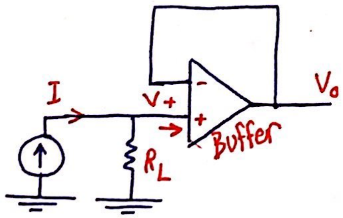
Range $\pm I_m$

↓

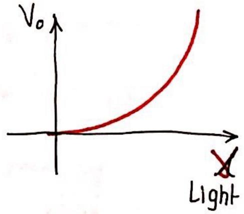
$\pm i_i = \pm I_m$

let $V_i = \mp 1V \Rightarrow R_i = 1K$

Current to voltage Converter



$V_o = V_+ = I.R_L$

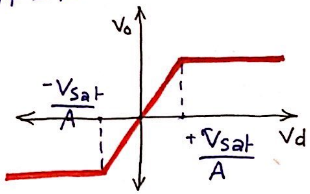


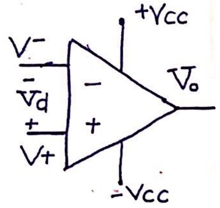
Op-amp as a Comparator (non-linear application)

1. $V_o = \pm V_{sat}$, $V_d = V_+ - V_-$

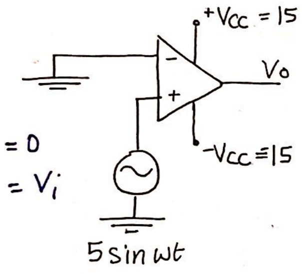
If $V_D > 0 \rightarrow V_o = +V_{sat}$

$V_D < 0 \rightarrow V_o = -V_{sat}$





Comparator: Zero level detector



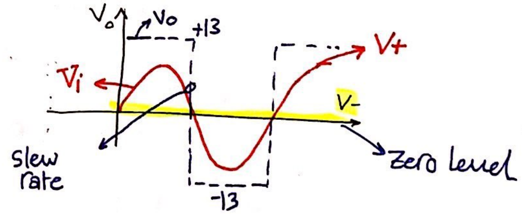
$V_- = 0$

$V_+ = V_i$

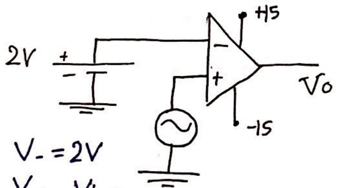
$V_o = \pm V_{sat} = \pm 13V$

When $V_i > 0 \rightarrow V_o = +13V$

When $V_i < 0 \rightarrow V_o = -13V$



Non-zero Level detector



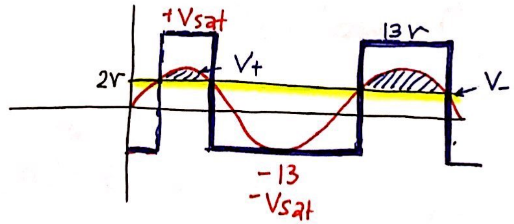
$V_- = 2V$

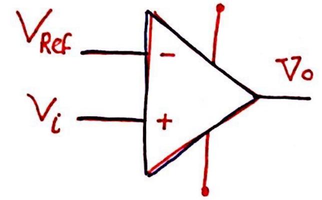
$V_+ = V_i$ sine wave

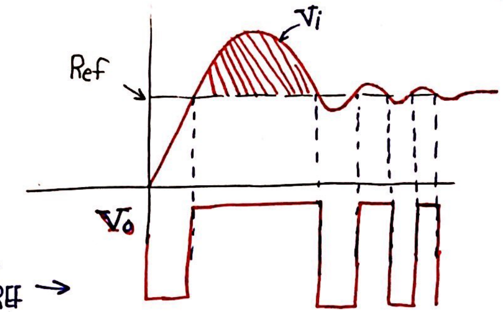
$V_o = \mp 13$

When $V_i > 2 \rightarrow V_o = +13$

When $V_i < 2 \rightarrow V_o = -13$



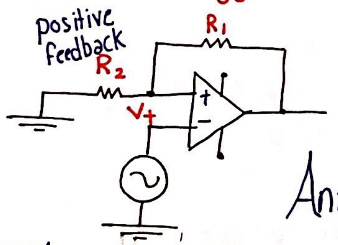




When V_i ascillates around V_{REF} →
V_o keeps changing between $\pm V_{sat}$

This is bad ⇒ use Comp. with ∓Ve Feedback (Hyst.) Schmitt triger

Schmitt trigger



This ~~A~~ is a Comparator

$V_o = \mp V_{sat}$

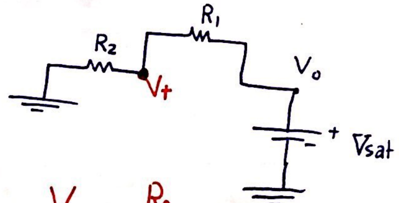
Analysis Method:

Step1: Let $V_o = +V_{sat}$

$\therefore V_d > 0$

$V_d = V_+ - V_- > 0$

$V_+ > V_i = V_{(-)}$



$$V_+ = \underbrace{\frac{R_2}{R_1 + R_2}}_{} \cdot (V_{sat})$$

V_{UT} "Upper Treshold"

As Long As

$V_{UT} > V_i \rightarrow V_o = +V_{sat}$

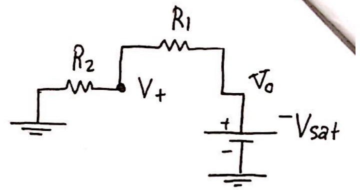
If V_i ↑ & becomes $> V_{UT}$ → ∴ V_o switches from $+V_{sat}$ to $-V_{sat}$

Step 2: Let $V_o = -V_{sat}$

$$V_+ < V_- = V_i$$

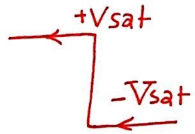
$$V_+ = \frac{R_2}{R_1 + R_2}(-V_{sat})$$

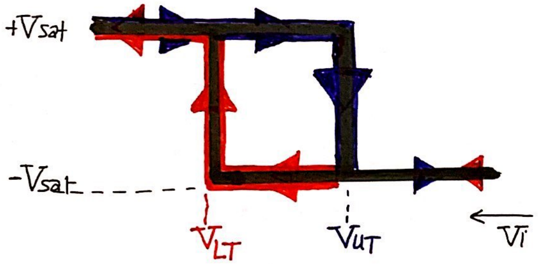
$$= V_{LT}$$ "Lower Treshold"



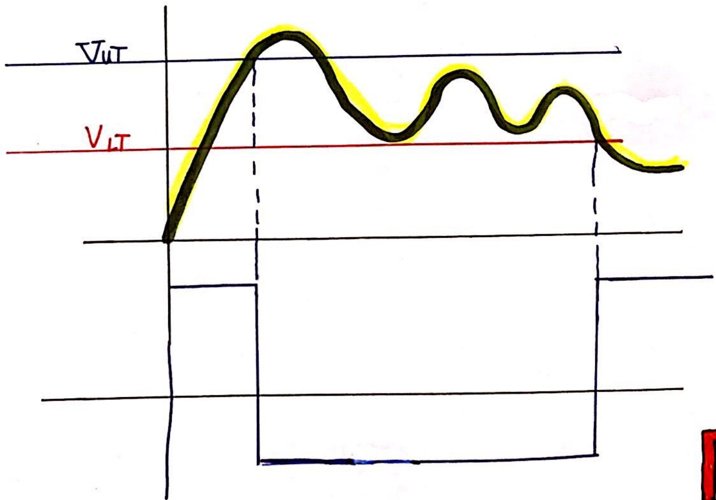
as long as $V_{LT} < V_i \Rightarrow V_o = -V_{sat}$

if $V_i \downarrow$ & becomes $< V_{LT} \Rightarrow$ Vo switch from $-V_{sat}$ to $+V_{sat}$



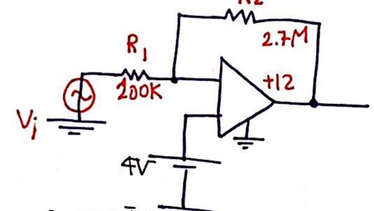


Switching هون عملية ال
مرة واحدة فقط



Electronics 236 → L21, Part 1 Opamp Active filters

Example : assume V_i is sine wave
1- find & Sketch $V_o(t)$
2- find & Sketch $V_o = f(V_i)$



$\therefore V_o = \pm V_{sat}$

$\therefore +V_{sat} = 12 - 2 = 10\ V$

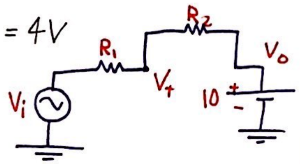
$-V_{sat} = 0 + 2 = 2\ V$

Solution: this is the Schemitic Triggar "Positive feedback"

[1] let $V_o = +V_{sat} = 10$

$V_+ > V_-$; but $V_- = 4V$

Find V_+ ?



Eq. circuit : two-Sourses → Use superpos.

Kill $V_i \Rightarrow V_+ = \frac{R_1}{R_1 + R_2} \cdot 10 = \frac{0.1}{2.8} \cdot 10 + \frac{R_2}{R_1 + R_2} \cdot V_i > V_- = 4$; $\frac{R_2}{R_1+R_2} \to \frac{2.7}{2.8}$

$V_i > \left(4 - \frac{1}{2.8}\right) \cdot \frac{2.8}{2.7} = 3.777$

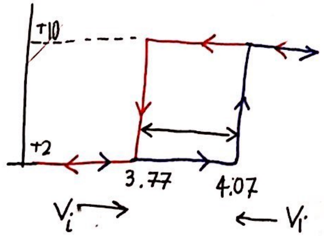
but when $V_i \downarrow < 3.77 \rightarrow V_o$ From $+V_{sat}$ to $-V_{sat}$

[2] let $V_o = -V_{sat} = 2$

$V_+ < V_- \Rightarrow V_+ = \frac{R_1}{R_1 + R_2} \cdot 2 + \frac{2.7}{2.8} V_i < 4$

$V_i < \left(4 - \frac{0.2}{2.8}\right) \times \frac{2.8}{2.7} = 4.07\ V$

When $V_i < 4.07$, $V_o = -V_{sat}$ & switches ~~from~~ to $+V_{sat}$ if $V_i > 4.07V$

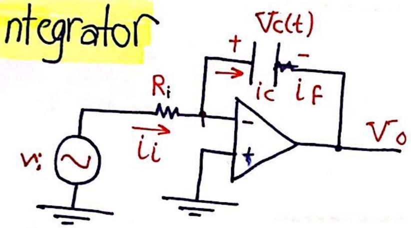


Hysteresis = 4.07 - 3.777 = 0.3 V

Other OP-Amp Applications

- Active filters (To remove loading effect & provide Gain)
- Integrator
- Differentiator

Integrator



$I_i = I_c = I_f = \frac{V_i}{R_i}$

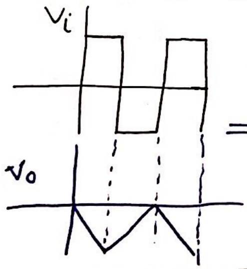
$I_c = C \frac{dV_c}{dt}$

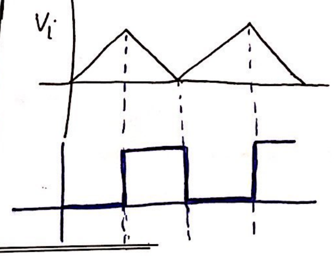
$\therefore V_c(t) = \frac{1}{C}\int_0^T i_c(t)\, dt$

also $V_o = -V_{c(t)}$

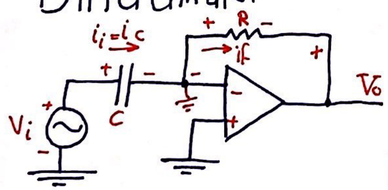
$V_o = -\frac{1}{C}\int_0^T \frac{V_i(t)}{R_i} dt = \frac{-1}{RC}\int V_i(t)\, dt$ "Output is $\int$ of Input"

يعني لما احط قيم موجبة بطلع متناقص ولما احط قيم سالبة بطلع متزايد





Differentiator



$i_c = i_i = i_f$

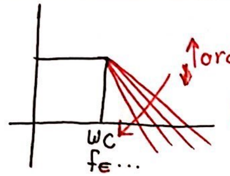
$i_c = C \frac{dV_c}{dt}$

$V_o = -I_f R$

$V_o = -RC \frac{dV_c}{dt} \Rightarrow V_o = -RC \frac{dV_i}{dt}$

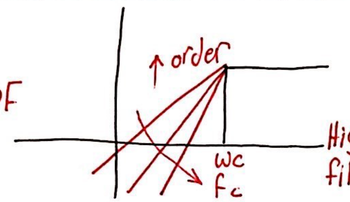
Filters

LPF



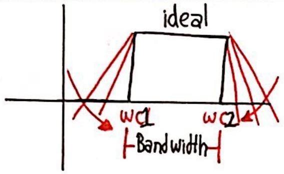
low Pass filter

HPF

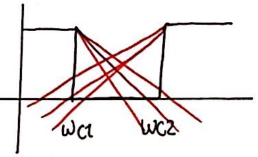


High Pass filter

Band Pass filter



Band reject filter

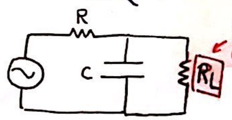


Filters

Passive : R, L, C ← Filters → Active : R, C, op-amps

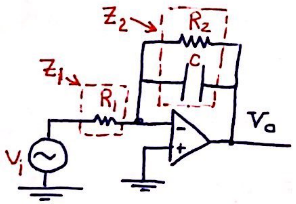
- Gain ≤ 1

- Gain ← >1, <1



$w_c = \frac{1}{RC} \rightarrow$ Av↓, $w_c \rightarrow$ changes $\rightarrow w_c = \frac{1}{R_{eq} \cdot C}$

Active low pass filter



$$V_o = -\frac{Z_2}{Z_1} \cdot V_i$$

$$A_v = \frac{V_o}{V_i} = \frac{-Z_2(jw)}{Z_1(jw)}$$

$$\rightarrow \frac{1}{jwc}$$

$$Z_1(jw) = R_1$$

$$Z_2(jw) = R_2 \parallel \frac{1}{jwc}$$

$$Av = \frac{\frac{-R_2 \cdot \frac{1}{jwc}}{R_2 + \frac{1}{jwc}}}{R_1} = \boxed{\frac{-R_2}{R_1}\left[\frac{1}{(1 + jwcR_2)}\right]} \dots (1)$$

Define $w_c = 2\pi f_c = \frac{1}{R_2 C}$ ← Cut-off freq.

$k = \frac{R_2}{R_1}$ (dc gain)

Sub in [1] $A_c = \frac{-K}{1 + \frac{jw}{w_c}}$ ⟹ frequency response

- magnitude $| \; |$
- phase $\angle$

A_c ← Complex → mag $| \; |$, phase $\angle$

Magnitude plot ← Bodé plot

X-axis $\log f, \log \omega$ ← indecade "when move from 10 to 100 it's here as 1→2"

Y-axis $20 \log | \; |$ ← In decibels **dB**

$$|A(jw)| = \frac{K}{\sqrt{1 + (\frac{\omega}{w_c})^2}} ;$$

$20 \log |A(jw)|$ ← Evaluation for different w's

if $k=1$ $| \; | = \frac{1}{\sqrt{1 + (\frac{w_c}{w_c})^2}} = \frac{1}{\sqrt{2}}$ (عند ال Cutoff)

$20 \log 0.707 = $ **-3 dB**

$k=10$ $20 \log \frac{10}{\sqrt{2}} = 20 \log 10 - 20 \log \sqrt{2}$

$20 - 3 \text{ dB} = 16.98$

("maximum - 3 dB يعني")

نلاحظ انو كل ما ضربنا ال w x10 كل ما نقص اختلال ال 20log|| بمقدار 20

---

if $w = 0.1 w_c$

$$20 \log \frac{1}{\sqrt{1 + (\frac{0.1 w_c}{w_c})^2}} = 20 \log \frac{1}{\sqrt{1.01}} \cong \textbf{0 dB}$$

if $w = 10 w_c$

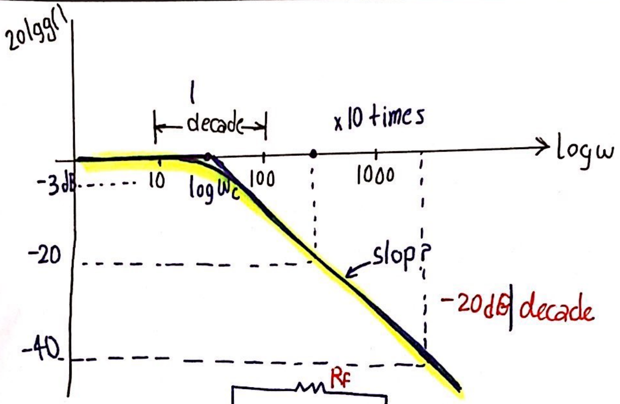
$$20 \log \frac{1}{\sqrt{1 + (10)^2}}$$

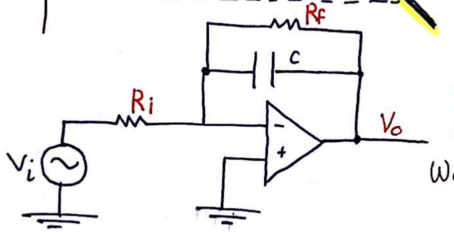
$$= 20 \log \frac{1}{\sqrt{101}}$$

$\cong$ **-20 dB**

Filter

magnitude freq. Response

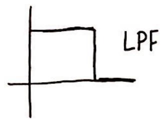




Filter Type?

$W = 0 \rightarrow C \rightarrow$ open

$V_o = \frac{-R_F}{R_i} \cdot V_i \neq 0$

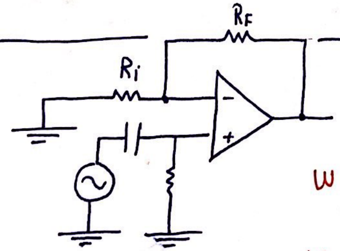


Qualative Analysis

$W = W_c$

$W = \infty \rightarrow C \rightarrow$ Short

$V_o = 0$



$V_o = (1 + \frac{R_F}{R_i})$

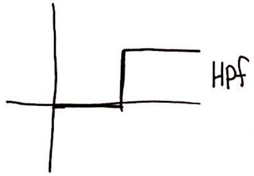
$W = 0 \Rightarrow C \rightarrow$ open

$V_o = 0$

$W = W_c$

$W = \infty \Rightarrow C \rightarrow$ short

$V_o \neq 0$



$R_2 \rightarrow$ affect gain

R_1 & $C \rightarrow$ Cut off freq.

Bode' plot

$$|A(jw)| = \frac{K}{\sqrt{1+\left(\frac{w}{wc}\right)^2}}$$, when $w = wc$ & $K = 1$

$$|A(jw)| = \frac{1}{\sqrt{1+\left(\frac{wc}{wc}\right)^2}} = \frac{1}{\sqrt{2}} = 0.707$$

$$20\log 0.707 = -3dB$$

When K=10

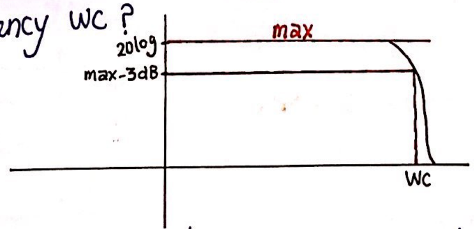
$$20\log\frac{10}{\sqrt{2}} = \overbrace{20\log 10}^{20} - 20\log\sqrt{2}$$

$$= +17\,dB$$

Note : when $W = Wc$ always value in decibels equal the maximum $-3dB$

$W = \frac{1}{RC}$ "Called cutoff frequancy"

Cutoff frequency wc ?



@ $w = 0.1\,wc \Rightarrow 20\log\frac{1}{\sqrt{1+\left(\frac{0.1wc}{wc}\right)^2}} = 20\log\frac{1}{\sqrt{1+0.01}} = \frac{1}{\sqrt{1.01}} \approx 0dB$

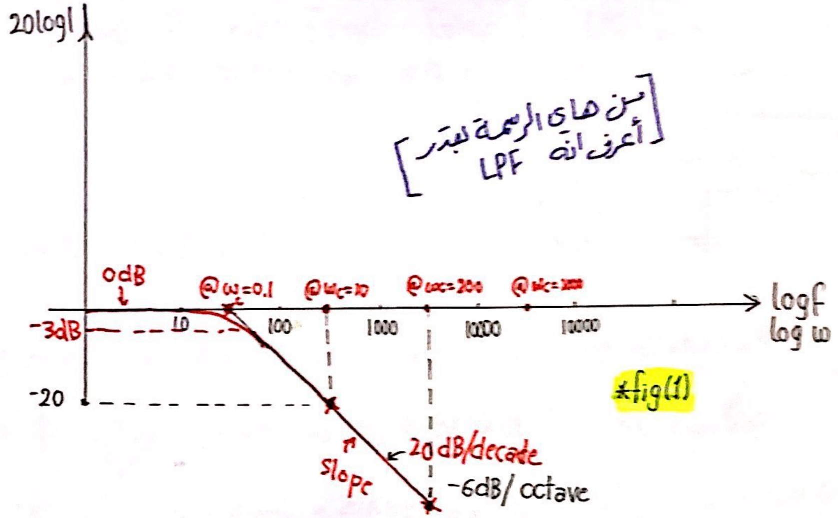
@ $w = 10\,wc \Rightarrow 20\log\frac{1}{\sqrt{1+\left(\frac{10wc}{wc}\right)^2}} = 20\log\frac{1}{\sqrt{101}} \cong -20dB$

@ $w = 100\,W_c \Rightarrow 20\log\frac{1}{\sqrt{1+(100)^2}} \cong 20\log\frac{1}{100} \cong -40\,dB$

@ $w = 1000\,W_c \Rightarrow 20\log\frac{1}{\sqrt{1+(1000)^2}} \cong -60\,dB$

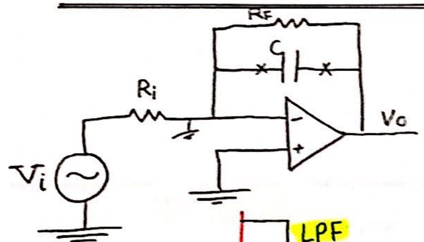
Note : كل ما ضربنا wc x 10 كل ما نقص
المقدار بمقدار 20 dB

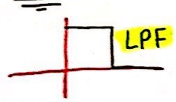
L21, Part 2, Opamp Active filter



*fig(1)

20 → -6dB/octave
40 → -12dB/octave
60 → -18dB/octave
للعلم





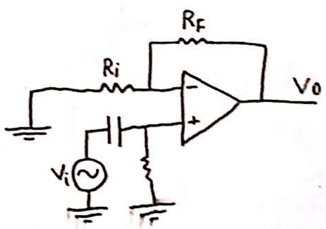
Filter type ? LPF/HPF ? **Inverting**

Qualative analysis

$\omega c = 0 \rightarrow C \rightarrow$ open // $V_o = \frac{-R_F}{R_i} \cdot V_i \neq 0$

$\omega = \omega_c$

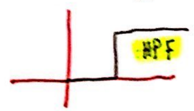
$\omega = \infty \rightarrow C \rightarrow$ short // $V_o = 0$ "Virtually Ground"



$\omega c = 0 \rightarrow C \rightarrow$ open // $V_o = 0$

$\omega = \infty \rightarrow C \rightarrow$ Short // $V_o \neq 0$ $\left(1 + \frac{R_F}{R_i}\right) V_i$

Non Inverting



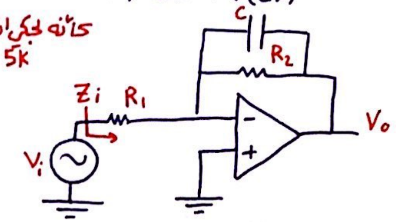
$f_{oH} = \frac{1}{2\pi RC}$

Active filter

يعني بالجزء الثابت من fig(1)

Active LPF filter Example: Given 1-st LPF, with $A_{v(dB)} = 40dB$

$\omega_c = 2\pi(20kHz)$, $Z_{in} = 5k\Omega$ كأنه حكى انه قيمة $R_1 = 5k$



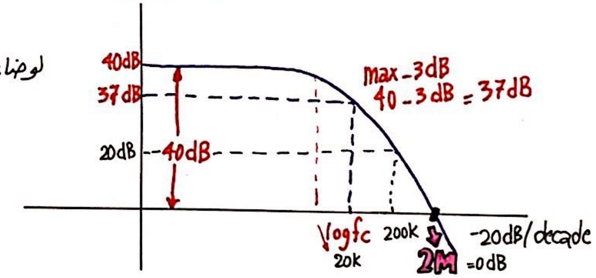
Solution: • $A_v = \dfrac{-K}{\left(1+\frac{j\omega}{\omega_c}\right)}$;

• $20\log A_v = 40\ dB \Rightarrow A_v = (10)^{40/20}$ @ $\omega = 0 \Rightarrow A_v = 100 = K$] لحساب قيمة K أو الـ Gain

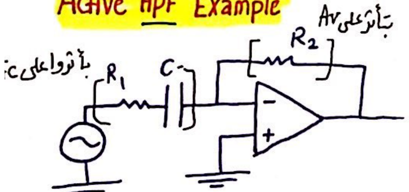
• $K = \dfrac{R_2}{R_1}$, $R_1 = 5K \Rightarrow R_2 = 500k\Omega$] لإيجاد قيمة R_2

• $f_c = \dfrac{\omega_c}{2\pi} = \dfrac{1}{2\pi R_2 C} = 20KHz \Rightarrow \therefore C = \dfrac{1}{2\pi(500k)(20k)} = 159\ pf$

لو ضاعفنا fc عشرة ← 200k "كم الـ decade in dB"



Active HPF Example



let $\dfrac{1}{R_1 C} = \omega_c$, $-R_2/R_1 = -K$

$$A_v = \frac{-R_2}{R_1 + \frac{1}{j\omega c}} = \frac{-R_2/R_1}{1 + 1/j\omega c R_1} = \frac{K}{\left(1+\frac{\omega_c}{j\omega}\right)}$$

$\omega_c = 2\pi f_c \Rightarrow f_{oH} = \dfrac{1}{2\pi R_1 C_1}$

$$\left[\ \omega_c = \frac{1}{RC},\quad K = \frac{R_2}{R_1}\ \right]$$

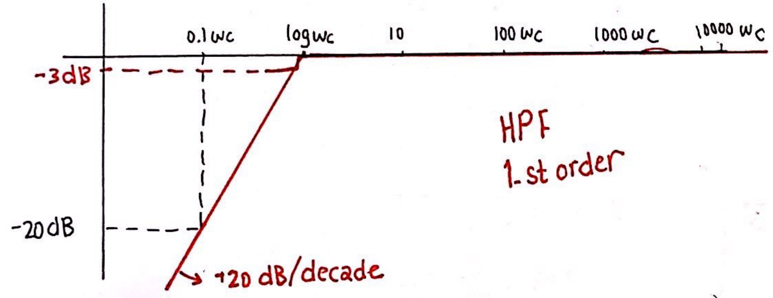
$20\log|A| = 20\log \dfrac{K}{\sqrt{1+\left(\frac{\omega_c}{\omega}\right)^2}}$ @ $K=1$

for $\omega = \omega_c \Rightarrow 20\log\dfrac{1}{\sqrt{2}} = -3\ dB$

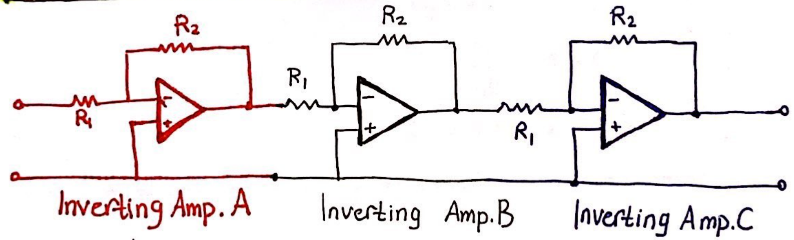
for $\omega = 0.1\omega_c \Rightarrow 20\log\dfrac{1}{\sqrt{101}} = -20\ dB$

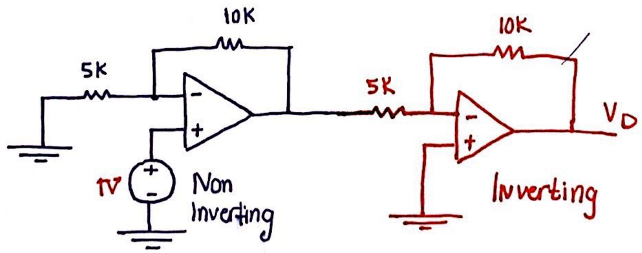
for $\omega = 0.01 \Rightarrow 20\log \Rightarrow \dfrac{1}{\sqrt{10001}} = -40\ dB$

Opamp Active filter



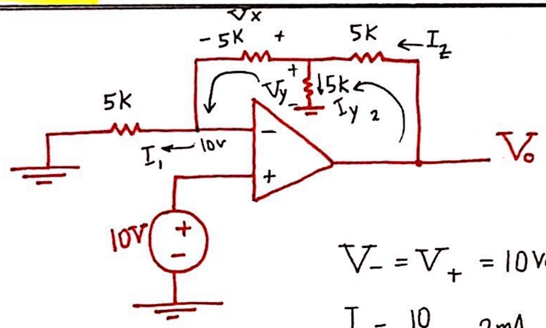
Cascaded Amplifiers





- $V_D = V_B\left(\frac{-10}{5}\right) = -2V_B$
- $V_B = \left(1+\frac{10k}{5k}\right) \times 1V = 3V$
- $V_D = -2 \times 3 = -6$ Volt

Opamp's



$V_- = V_+ = 10\,\text{Volt}$

$I_1 = \frac{10}{5k} = 2mA$

$V_x = 2mA \times 5k = 10\ \text{volt}$

$V_y = V_x + 10 = 20\ v$

$I_y = \frac{20}{5k} = 4\ mA$

$I_z = 4mA + 2mA = 6mA$

KVL 2

$V_o = V_z + V_y$

$= 6m \times 5k + 20$

$= \underline{\underline{50\ v}}$

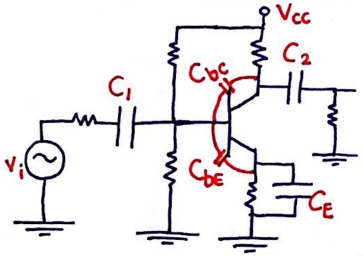
Amplifier Frequancy Response : Magnitude freq Response **only**!

- We will consider the Impedance of capacitor ($\frac{1}{jwC}$) when Finding AV of BJT & FET amplifiers.

- The Bandwidth of Amplifiers must cover the entire range of frequency of Intrest.

- Depending of nature of signals to be amplified, different requirments (BW) is imposed on Amplifiers
  (BW = Band width)

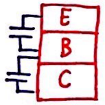
- Amplifier frequency response Is defined by external & Internal amplifier Caps & Impedence.



C_1, C_2, C_E ← External Caps "physical Caps"

$A_V \big|_{C_1, C_2, C_E \text{ "Short Circuit"}}$

(But, Internal Caps) بالبيكو فاراد

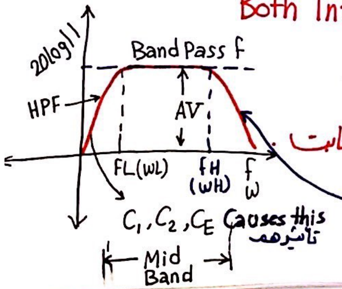


// PCB, mother boards
Between trases "conducters"

Both Internal Caps we call **stray** or **Parasitic**

"الطفيليات" Parasites من كلمة

كنا نخطهم open "نعتبرهم" وكان الـ Gain يطلع ثابت

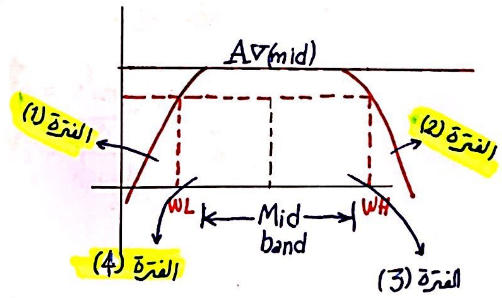


اللي بأثر علينا هو:
C_{be}, C_{bc}, C_{gs}
C_{gd}

إذا طُلب منا نطلع $A_{v_{mid}}$ بنحط الـ Caps $(C_1, C_2 \& C_E) \Leftarrow$ Short
و " الـ Caps $(C_{bc}, C_{bE}) \Leftarrow$ open

Band width $\equiv$ Mid Band $\Rightarrow$ هي المنطقة اللي ضمنها الـ Amplif بمرر الـ Components بدون ما يعمل Attenuation "تقليل تأثير" بعمل Amplification

$F_L \& F_M \Rightarrow \frac{Maximum}{\sqrt{2}}$



- Corner (cut_off) frequancy
- $A_v(jw_L) = \frac{A_v(mid)}{\sqrt{2}}$
- $A_v(jw_H) = \frac{A_v(mid)}{\sqrt{2}}$
- $W_H - W_L = BW$
- Mid band $\approx 10w_L - 0.1 * W_H$ // this is the range for which $C_1, C_2 \& C_E$ were considered short & $C_{gs}, C_{be}, C_{gd}, C_{bc}$ where considered open

---

Impedence of capacitor $\rightarrow X_C = \frac{1}{2\pi f c}$

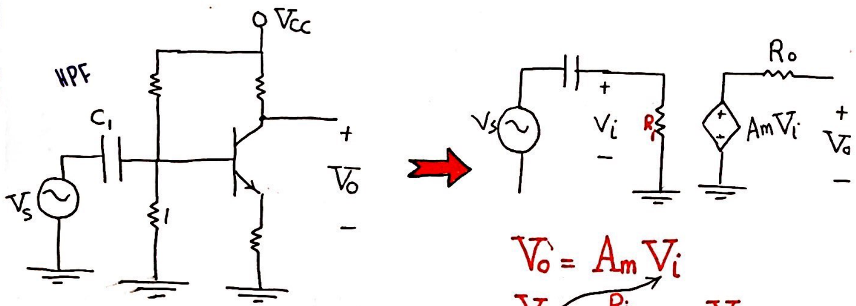
$Z_C = \frac{1}{jwc}$

1. for $f < f_L \rightarrow X_{C1}, X_{C2}, X_{CE} > 0$ & connot be concidered short as was done In L11 & L9

2. for $f > f_H \rightarrow$ Parasitic Caps (in pF) cannot be considered open as X_{Cbe}, X_{Cbc} $X_{Cgd} \& X_{Cgs}$

- الفكرة انو اذا بنحكي عن الفترة (1) معناته لازم نرجع C_1, C_2, C_E والبقية open.
- " " " " الفترة (2) معناته لازم نخلي $C_{be}, C_{gs}, C_{gd}, C_{bc}$ Short والباقي open.
- اما بالفترة (3) اللي اسمه BW بكون الـ C_1, C_2, C_E شورت و open.
- اما بالفترة (4) بكون C_1, C_2, C_E open و الباقي شورت.

Series Capacitance & w_L



$$V_o = A_m V_i$$

$$V_i = \frac{R_i}{R_i + \frac{1}{jwc}} \cdot V_s$$

$$\frac{V_o}{V_s} = \frac{A_m R_i}{R_i + \frac{1}{jwc}} \quad , A_m \equiv A_v(mid)$$

$$|A_v(jw)| = \frac{A_m R_i}{\sqrt{R_i^2 + \left(\frac{1}{wC_1}\right)^2}} \quad , \quad 1 \Leftarrow \frac{1}{wc} \text{ نعوض محل}$$

صون ضرب

$$w_{C1} = \frac{1}{R_i C_1}$$

Cut-off due to C1
"مش ضرب"

$$A_v(jw) = \frac{A_m}{\sqrt{1 + \left(\frac{w_{C1}}{w}\right)^2}}$$

HPF

- Let $A_m = 1$, $w = w_{C1} \rightarrow |\ | = \frac{1}{\sqrt{1+1}} = \frac{1}{\sqrt{2}} \Rightarrow 20\log\frac{1}{\sqrt{2}} = -3dB$
- Let $w = 0.1\, w_{C1} \rightarrow |\ | = \frac{1}{\sqrt{1+100}} \cong 0.1 \Rightarrow 20\log 0.1 \cong -20dB$

1. If only $C1 \rightarrow w_{C_1} = w_L$
2. If $C_1 \& C_2 \rightarrow w_L$?

$$A(jw) = A_m\left(\frac{1}{1 + \frac{w_{C1}}{jw}}\right)\left(\frac{1}{1 + \frac{w_{C2}}{jw}}\right)$$

$$|A(jw)| = \ldots$$

$$|A(jw_L)| = \frac{A_m}{\sqrt{2}} = \ldots$$

→ Solving for w_L :

$$(w_L)^2 = \frac{w_{C1}^2 + w_{C2}^2}{2} + \frac{\sqrt{w_{C1}^4 + 6w_{C1}^2 w_{C2}^2 + w_{C2}^4}}{2}$$

حل من تفكيك الاقواس وعمل الـ Magnitude للمقدار ومساواة الـ (evaluation for w_L)

1) W_{C1} = 616 rad/sec

W_{C2} = 17.86 rad/sec

⋮

W_{C3} =

⋮

W_L = 616.5 rad/sec

2) W_{C1} = 200 rad/sec

W_{C2} = 750 rad/sec

W_L = 798 rad/sec

$W_L > \max(j w's)$ حتى لو شو ما كان عدد الـ Caps // $\Sigma w's > W_L$

$$\Sigma W's \geq W_L \geq \max(w's)$$

1 Calculate each Wc alone.

$$W_{C_1} = \frac{1}{C_1 R_{eq1}}$$ ← اللي بشوفها الـ Cap(1)

$$W_{C2} = \frac{1}{C_2 R_{eq2}}$$ ← اللي بشوفها Cap(2)

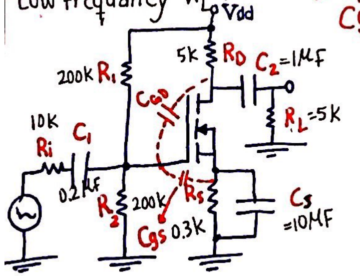
2 Estimate W_L:

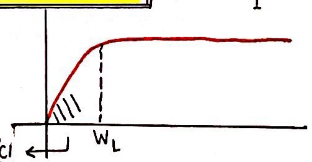
Max of w's $\leq W_L \leq$ sum of W's

L22, Part2 / Amplifer Frequency Response

Example

Low frequancy W_L? → Cgd, Cgs > open



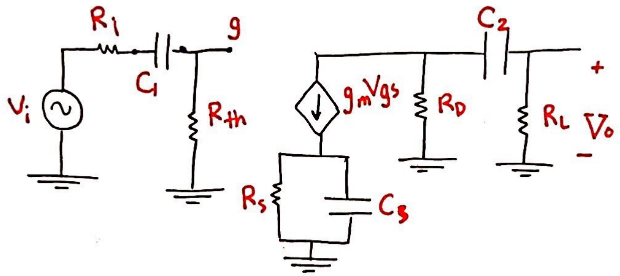


C_2, C_s "SC" ← $1/C_1 R_{eq}(C_1) = W_{C1}$

C_1, C_s "SC" ← $1/C_2 R_{eq}(C_2) = W_{C2}$

C_1, C_2 "SC" ← $1/C_s R_{eq}(C_s) = W_{C3}$

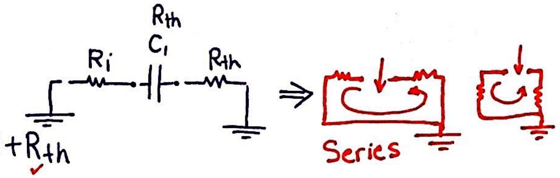
Ac ss Low Frequency Eq. Circuit



1 $W_{C1} = \frac{1}{C_1 \, Req(C1)}$

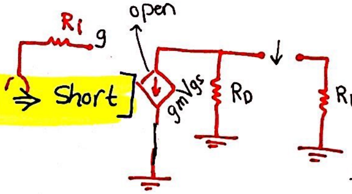
$Req(C_1) = R_{th}|_{\text{Seen by } C_1} = R_{th}|_{V_i=0} = R_i + R_{th}$

Kill Indep. sources



$W_{C1} = 45.45$ rad/sec

2 $W_{C2} = \frac{1}{C_2 \, Req(C_2)}$ ⇒ [C_1, C_s ⇒ Short]



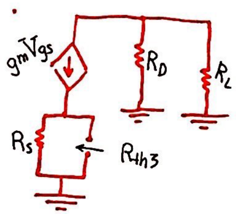
, $V_{gs} = 0$ (حسب الرسمة)

then $V_{gs} \cdot g_m = 0$ "open"

$Req(C_2) = R_D + R_L$

$W_{C2} = 100$ rad/sec

3 $W_{CS} = \frac{1}{C_S \, R_{th}(3)}$ ⇒ [C_1, C_2 ⇒ Short]



$R_{th}(3) = R_S \,//\, \frac{1}{g_m}$

$r_{ds} \to \infty$

$W_{CS} = 1050$ rad/Sec

$W_{C1} = 45.45$ rad/sec
$W_{C2} = 100$ rad/sec
$W_{CS} = 1050$ rad/sec

max < W_L < ~~ma~~ sum

$1050 \leqslant W_L \leqslant 1195.45$

Design for Certain ω_L ← given "1000 rad/sec"

$$\max(\omega's) \ll \omega_L \ll \omega_1 + \omega_2 + \cdots \omega_n$$

assume $\omega_L = \omega_{C1} + \omega_{C2} + \omega_{CS}$

[بدنا نقسم الـ 1000 على 3Caps بس مش بالتساوي]

[Design Criteria]

$$\omega_{CE} \text{ or } \omega_{CS} = \left(\frac{70}{100} - \frac{80}{100}\right)\omega_L = (0.7 - 0.8)\,\omega_L$$

بتوخذ اكبر حصة زي ما شفنا بالمثال السابق

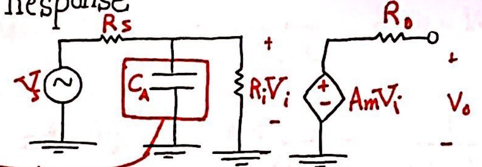
$$\omega_{C_1} = \omega_{C_2} = (0.1 - 0.15)\,\omega_L$$

$$\Sigma = \omega_L$$

Electronics 236_L23, Part1&2 _Frequency Response

Shunt Caps & high Frequancy Response

بين G و S
اوبين B و E



$V_o = A_m V_i$, Am Gain @ mid band

$$V_i = \frac{R_i // \frac{1}{j\omega C_A}}{R_i + \frac{1}{j\omega C_A} + R_s} \times V_s$$

$$A(j\omega) = A_m \left(\frac{R_i}{R_i + R_s}\right) \cdot \left(\frac{1}{1 + j\omega C_A (R_s // R_i)}\right)$$

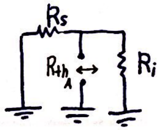
$$|A(j\omega)| = A_m \frac{R_i}{R_i + R_s} \frac{1}{\sqrt{1 + [\omega C_A R_s // R_i]^2}} \quad ; \ @ \ \omega = \omega_{CA}$$

$$\therefore |A(j\omega_{CA})| = A_v(mid) \frac{1}{\sqrt{2}}$$

($A_v(mid)$ ← $A_m \frac{R_i}{R_i + R_s}$)

$\therefore \rightarrow \omega_{HCA} (R_s // R_i) = 1 \Rightarrow \omega_H = \frac{1}{C_A (R_s // R_i)}$ ← high freq. Corner freq.

$(R_s // R_i) \equiv R_{th_A} \Big|_{V_s = 0}$ thevenin's Impedence seen by CA



Parallel

[For $A_v(mid) = A_m = 1$]

@ $\omega = \omega_{CA} \rightarrow 20\log|\ | = 20\log \frac{1}{\sqrt{2}} = -3dB$

@ $\omega = 10\omega_{CA} \rightarrow 20\log 10 = -20 dB$

∴ This is LPF

Notes

1. If there is one Cap of this type we find $W_{CA} = \frac{1}{R_{thA} C_A}$; & $W_H = W_{CA}$

2. If there is two Caps C_A & C_B ➡ $A(jw) = A_v(mid) \frac{1}{(1+\frac{jw}{W_{CA}})} \cdot \frac{1}{(1+\frac{jw}{W_{CB}})}$ ← LPF

➡ To find W_H "على فرض انهم لا توالي ولا توازي _ بعاد عن بعض"

$$|A(jw_H)| = \frac{A_m(mid)}{\sqrt{2}} = \frac{A_v(mid)}{\left|(1+\frac{jw}{W_{CA}})(1+\frac{jw}{W_{CB}})\right|}$$

By solving For $|A(jw_H)|$ @ $w = w_H$, we get an approximate experssion to Evaluate W_H

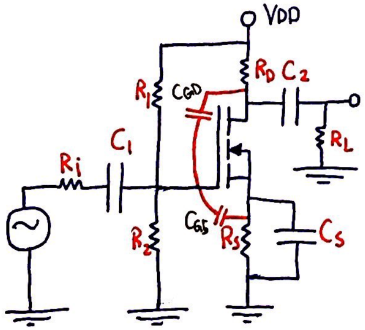
- Assuming $W_{CA} > W_{CB}$

$$1/\left(\frac{1}{W_{CA}} + \frac{1}{W_{CB}}\right) < W_H < W_{CB}$$

$$\frac{W_{CA} \cdot W_{CB}}{W_{CA} + W_{CB}} < W_H < W_{CB}$$

lower limit $< W_H <$ min $(W's)$

Example _ high Freq. W_H ?



اول سؤال هو شو هي الكاسترز اللي بـ اهوا بقيمة W_H
$[C_{GD}, C_{GS}]$

↳ C_1, C_2, C_S → short

C_{GD}, C_{GS} → are considered one @ a time while all other high freq are open

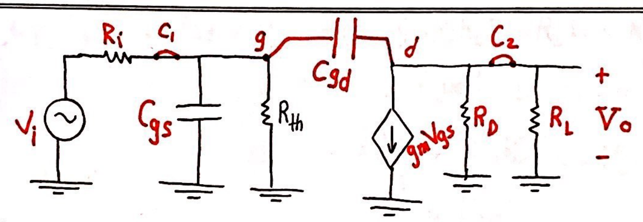
Example - High Freq.

- high Freq. ss Eq. Circuit.
  - ↳ $C_1, C_2, C_s \rightarrow$ Short
  - ↳ $C_{gs}, C_{gd} \rightarrow$ 1 @ a time, while others high freq. open!

- W_H is estimated using Formmula.

$$\frac{1}{\frac{1}{W_{CA}} + \frac{1}{W_{CB}}} \leq W_H \leq \min(W_n's)$$

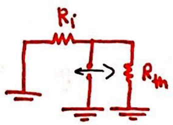
High Freq ss Eq. Ciruit



1. Consider C_{gs} (C_{gd} open)

$$W_{cgs} = \frac{1}{C_{gs} R_{gs}}$$

$R_{gs} \rightarrow$ هي عبارة عن المقاومة اللي بشوفها ال Cap لما كل ال Indep. Sources Killed

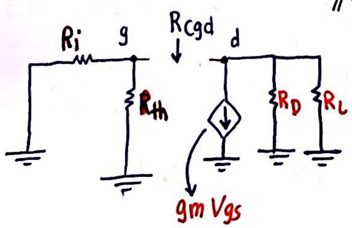


$$R_{gs}\Big|_{V_i=0} = R_i \,//\, R_{th}$$

W_{cgs} = 668.45 M rad/sec

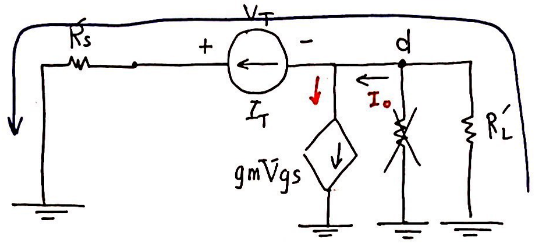
لو بدنا F بنقسم //(6.28)=2π (نفس القيمة)

2.



بنداخل السيركت على I_T , V_T

$$R_{gd}\Big|_{V_i=0} = \frac{V_T}{I_T}$$



- $I_o = I_T + g_m V_{gs}$
- $V_{gs} = V_g = I_T \times R_s'$
- $I_o R_L' + I_T R_s' = V_T$

$\rightarrow (g_m V_{gs} + I_T) R_L' + I_T R_s' = V_T$

$(g_m I_T R_s' + I_T) R_L' + I_T R_s' = V_T \Rightarrow g_m R_s' R_L' I_T + R_L' I_T + R_s' I_T = V_T$

$I_T (g_m R_s' R_L' + R_L' + R_s') = V_T$

$\therefore \frac{V_T}{I_T} = g_m R_s' R_L' + R_L' + R_s'$

$= R_{gs}$

[illegible]

2. Consider C_{gd} ($C_{gs} \rightarrow$ open)

$\omega_{gd} = \frac{1}{C_{gd} R_{gd}}$; R_{gd} is calculated using $\frac{V_T}{I_T}$ method.

$\omega_{gd} = \frac{1}{C_{gd} R_{cgd}} = 48.54\,M$ rad/sec.

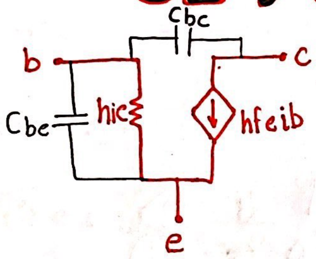
3. Estimation of ω_H

$$\frac{668 * 48}{668 + 48} \leqslant \omega_H \leqslant 48.58 \text{ Mrad/sec}$$

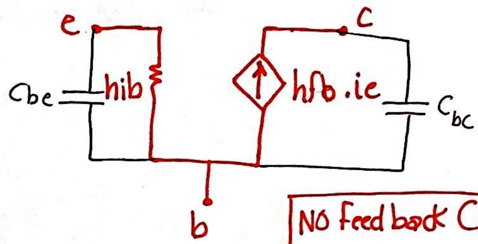
$$[45.25 \leqslant \omega_H \leqslant 48.58] \text{ M rad/sec}$$

BJT's

CE, CC



CB



NO feed back Cap

$$h_{fe} i_b = h_{fe} \cdot \frac{V_{be}}{h_{ie}}$$

$$= g_m \cdot V_{be}$$

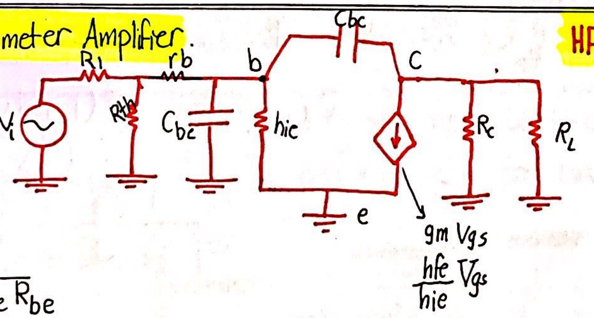
$$\boxed{g_m = \frac{h_{fe}}{h_{ie}}}$$

---

* Common Emmeter Amplifier

* Example

HF ac ss eq. Circuit

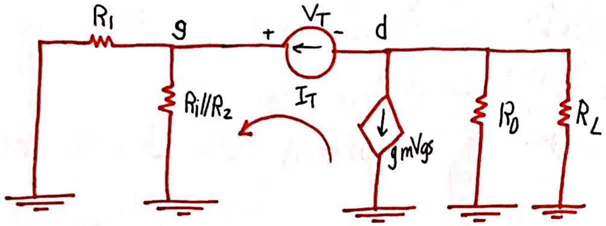


1 $w_{be} = \dfrac{1}{C_{be} R_{be}}$

$$R_{be}\Big|_{V_i=0} = ([R_1 // R_{th}] + r_b)$$

2 Consider C_{gd} ($C_{gs} \to$ open)

$$\omega_{gd} = \frac{1}{C_{gd} R_{gd}}$$; R_{gd} is calculated using $\frac{V_T}{I_T}$ method.



; $R_L, R_D, R_L' \to$ Parallel ?

Find ω_H?

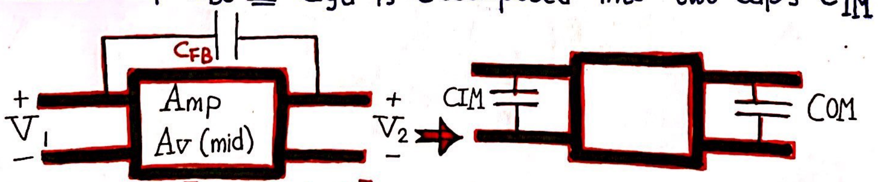
2 ~~Choose~~ $\omega_{be} = \frac{1}{C_{be} R_{be}} = \ldots$

$$R_{be}\Big|_{V=00} = R_i \,//\, (R_1 // R_{th}) + r_b)$$

Note To Self: FET → has high Freq Response Better than BJT

Miller Theorm: Used in Inverting amplifiers to find ω_H.

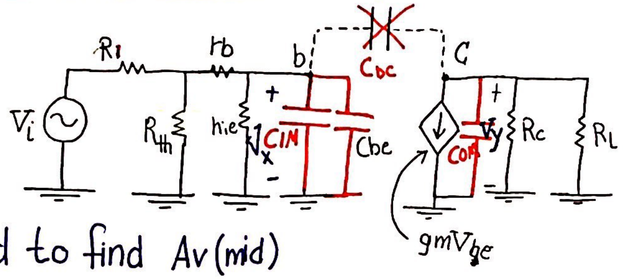
- Feedback Cap C_{bc} or C_{gd} is decomposed into two Caps C_{IM} C_{OM}



$$CIM = C_{FB}[1 - A_v(mid)]$$

$$COM = C_{FB}\left[1 - \frac{1}{A_v(mid)}\right]$$

Back to Example @ Page 5



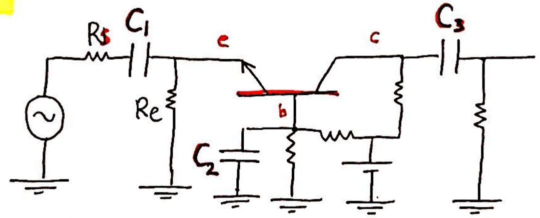
We need to find Av(mid)

- $A_v(mid) = \frac{V_y}{V_x}$, $C_{FB} = C_{bc}$

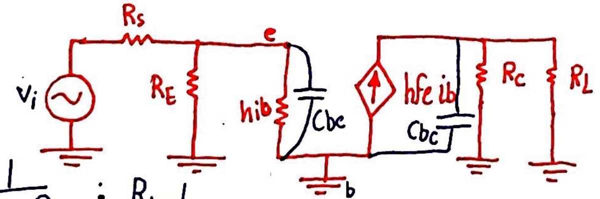
Miller Theorm

- $W_I = \frac{1}{(C_{be} + C_{IM}) R_I}$
- $R_I = R_{be}$ "found earlier" $= (R_1 // R_{th}) + r_d$
- $W_o = \frac{1}{C_{OM} R_o}$; $R_o|_{V_i=0} = R_c // R_L$

CB Example



WH



$w_{be} = \frac{1}{C_{be} R_{be}}$; $R_{be}|_{V_i=0} = R_s // R_E // h_{ib}$

$w_{bc} = \frac{1}{C_{bc} R_{bc}}$; $R_{bc}|_{V_i=0} = R_c // R_L$

7 $\frac{w_{bc} \times w_{be}}{w_{bc} + w_{be}} \leq W_H \leq \min(w's)$

Homework →

Estimate the value of low & high frequency Corner frequencies & Calcultae the mid-range voltage gain of the following Amplifie

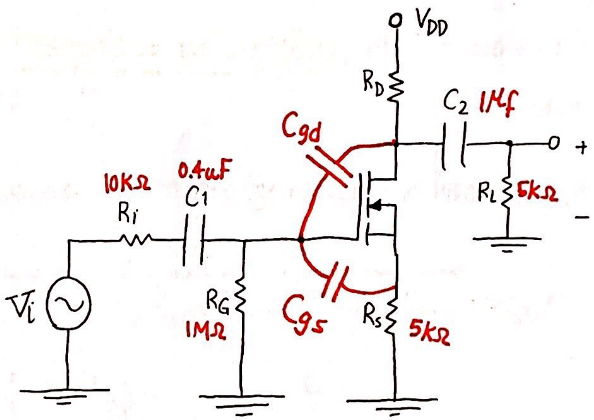
Important

$g_m = 1mS$

$C_{gs} = 5PF$

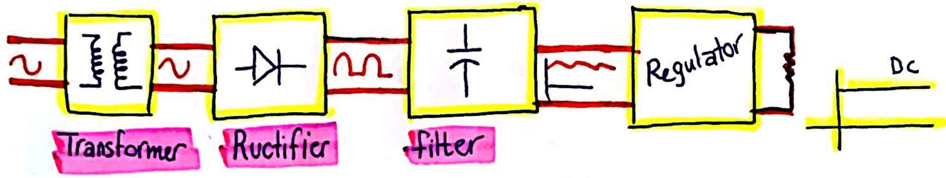
$C_{gd} = 2PF$

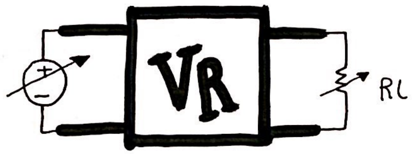
$R_1 = 200K\Omega$



Voltage Regulator

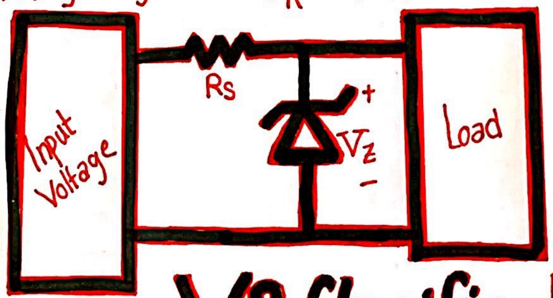
Dc Power Supply " Remind "





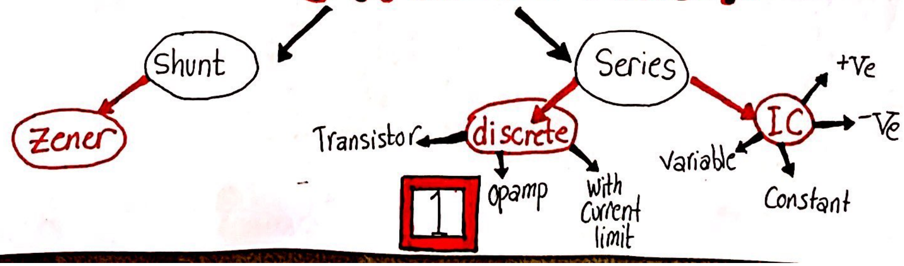
To keep $V_L \approx$ Constant ⩽ V_{in} ⩽ , ⩽ R_L ⩽

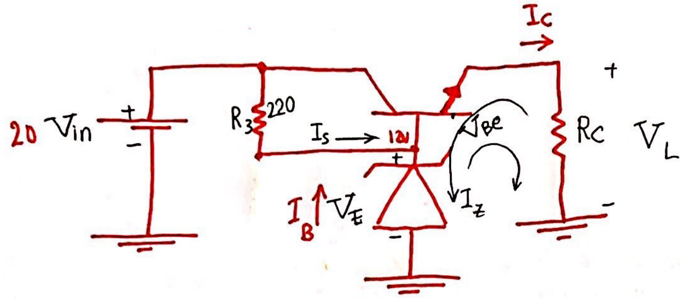
Simpliest Voltage Regulator : V_R → Zener "Shunt VR "Parallel""



VR Clasification

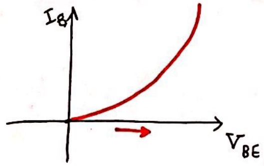
linear





$$V_L + V_{BE} = V_Z$$

$$V_L = V_Z - V_{BE} \leftarrow \text{control}$$



$$I_B = I_C\,(e^{\cdots}-1)$$

$$I_C = \beta I_B$$

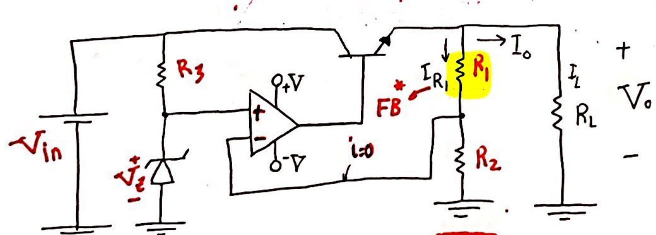
هون بتكون V_Z ثابتة ووظيفة ال Regulator هو انو يعدّل أي
خلل او نقصان بالفولتج ، يعني لو نقصت V_L احنا بنتحكم
ب V_{BE} وبنزيدها $V_L\downarrow ,\ V_{BE}\uparrow$
بعدها بتزيد I_C فبرجع بزيد $I_C\uparrow ,\ V_L\uparrow$
V_L وهيك بحافظ على نفس المستوى.

$\beta = 50$, $V_{in} = 20V$, $V_Z = 12V$,

لحساب I_Z

$I_Z = I_s - I_B$; $I_s \to$ mA , $I_B \to \mu A \Rightarrow$ ممكن اهماله // $I_Z \cong I_s$; $I_s = \dfrac{20-12}{220} \cong 36mA$

بدنا نعمل على السركت عشان نخلي كفاءتها اعلى



$R_1 \& R_2$ Sampling R's

$$I_{R_1} \ll I_L$$

$$V_- = \frac{R_2}{R_1+R_2} \cdot V_o$$

$$V_- = V_+$$

$$V_+ = V_Z$$

$I_{R_1} = I_{R_2}$ // $R_1 \Rightarrow$ feedback*

$$\frac{R_2}{R_1+R_2} \cdot V_o = V_z$$

$$V_- = V_+$$

$$V_o = \frac{R_1+R_2}{R_2} \cdot V_z$$

ممكن يكون المطلوب انو $V_o = 15\,V$ وهكالنا $V_z = 11\,V$ ✗ بس ما بنفع الا تكون اصغر

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

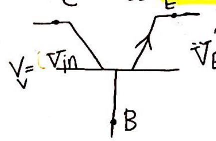
← almost constant

← non Inverting amp

- we can set V_o to any value by choosing V_z, R_1, R_2.

V_o always $\gg V_z$

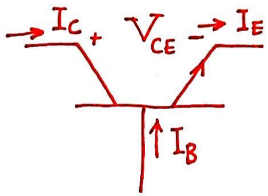
$$\boxed{V_z < V_o}$$



$$V_{CE} > V_{CE(sat)} + 2$$

$$V_{in} > V_o + 2$$

- Power dissipation of BJT



$P_Q \cong V_{CE} \cdot I_E <$ Power Rating given in data sheet

اذا كان الـ P_Q اكبر من Power Rating بنحرق عندنا الـ Transistor / due to rise in Temp.

ممكن نستخدم heat sink

Electronics 236 - L24 Voltage Regulators

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

لوكان المعطى ان $V_o=10V$ و المطلوب ايجاد قيم V_Z, R_1, R_2

$V_Z = 4V$
$7V$
$8V$
~~X~~ V

1. لازم قيمة V_Z اقل من V_o ولنفرض ان المعطيات ان

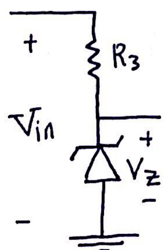
وفرضنا ان $V_Z=8$ ⇐ $1+\frac{R_1}{R_2} = \frac{10}{8} = 1.25$

$$\frac{R_1}{R_2} = 0.25$$

2. بنعرف أنه قيمة R_1, R_2 بال Range " 100's of Ω / KΩ's " والسبب ان هذا
التيار نريد ان يزود الـ load ← not R_1 & R_2

3. Let $[R_2 = 5k\Omega]$, $[R_1 = 1.25\Omega]$, $\frac{R_1}{R_2} = \frac{1}{4}$

هيك خلصنا design بس ما خلصنا الحل لانه ما اهتمينا بقيمة V_{in}.



$$V_{in} > V_Z$$

$$V_{CE} > V_{CE(sat)} \quad (0.2)$$

V_{CE} @ least $2V$

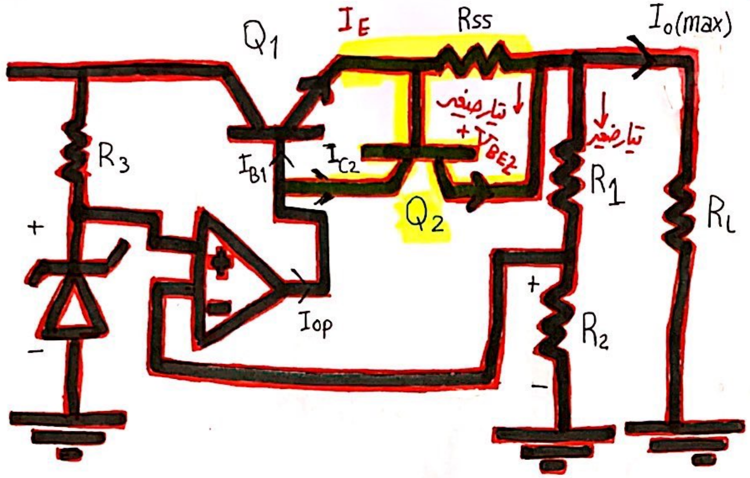
ليش 2 هو مش شرط 2 ولكن احنا اخذناها كـ Role of thump لانه لو كانت مثلاً 10 بصير عنا PQ عالي جداً وصعب الحصول عليه لهيك تطبيق:
$P_Q \cong I_E V_{CE}$

$$V_{CE} = V_C - V_E = V_{in} - V_o > 2$$

$$V_{in} > V_o + 2 \quad **$$

Short circuit Protection ≡ Current Limiting.

$I_E \approx I_o(max)$



$I_{limit} = I_o(max) = ?$

1 $I_L < I_o(max)$

$Q2 \rightarrow off \Rightarrow V_o = \left(1 + \frac{R_1}{R_2}\right) V_Z$

2 $I_L > I_o(max)$

$Q_2 \rightarrow ON \Rightarrow$

$V_{BE} \geq 0.7 \Leftarrow$ بكون ON / $V_{BE2} = I_E \cdot R_{(SC)}$

$$R_{(SC)} = \frac{V_{BE2}}{I_{limit}}$$

Design 4: $I_{limit} = 1.5A$ // الحل

$$R_{(SC)} = \frac{0.7}{1.5}$$

شرح للدارة :-

$I_{op} = I_{C2} + I_{B1}$ (ثابت I_{op})

$I_{B1} = I_{op} - I_{C2}$

[اذا زاد التيار I_{C2} بالتالي بقل I_{B1} ← I_{E1} ←بقل بقل I_L

معناته I_L مش رح يزيد عن ال limit.]

IN Current Limit Mode

$$V_0 = \left(1 + \frac{R_1}{R_2}\right) V_Z$$ "NoT valid"

$V_0 = R_L \cdot I_{Limit}^{1.5A}$ بتصير المعادلة

IC Voltage Regulator

Fixed

Positive
- 78XX
  - 05
  - 08
  - 12
  - ⋮
  - 24

Negative
- 79XX
  - 05
  - 08
  - 12
  - ⋮
  - 24

Variable adjustable

317 "most famous"

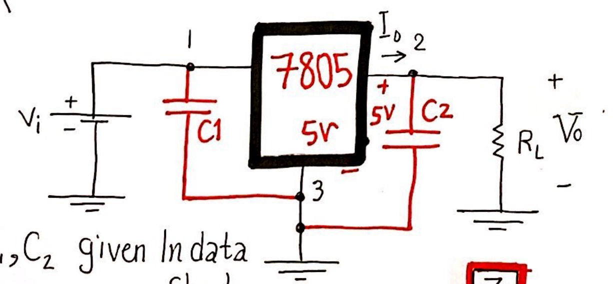
↓

From 2.25 – 35

↑

External resistors

Positive

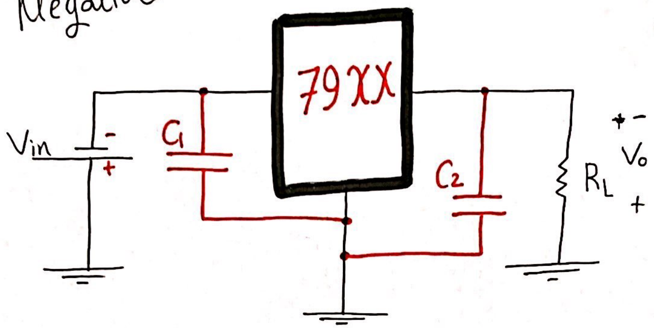


C_1, C_2 given In data Sheet

@least 2v

- $V_{in} > V_o + 2$
- $I_o < I_{max}$

Negative

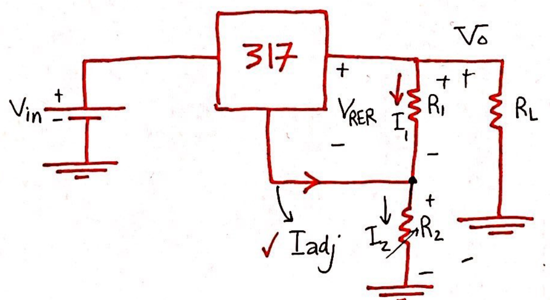


- $|V_{in}| > |V_o|$
- $I_o < I_{max}$

7909 → −9V

Adjustable VR 317

Important



$V_{REF} \cong 1.25\,v$

If $R_2 = 0 \Rightarrow V_o = 1.25\,v$

$R_2 \neq 0 \Rightarrow V_o > 1.25$

V_o = Voltage on R_1 + Voltage on R_2

$I_1 = \frac{V_{REF}}{R_1}$ و $I_2 = I_1 + I_{adj}$

$$V_o = I_1 R_1 + I_2 R_2$$
$$= I_1 R_1 + (I_1 + I_{adj}) R_2$$
$$= I_1 (R_1 + R_2) + I_{adj} R_2$$

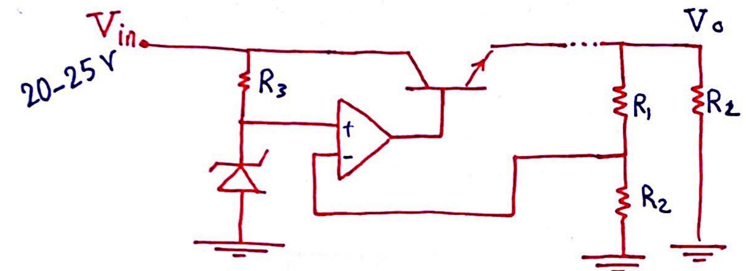
تعميم →

$1.25 \leq V_o \leq 35v$

$I_o \leq 1.5\,A$

بتغيير قيمة R_2 بقدر احصل على القيمة المرادة

Electronics 231 _ L25 Part 1&2 Voltage Reg 2



[1] Calculate R_1, R_2, R_3 → $V_o = 12V$

available $V_Z = 4V$ ✓

$V_Z = 12.7V$?

$I_Z(min) = 2mA$

First, $V_Z < V_o$ ⇒ we choose $V_Z = 4V$

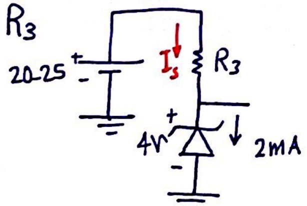
$$V_o = \left(1 + \frac{R_1}{R_2}\right) \cdot V_Z$$

$$12 = \left(1 + \frac{R_1}{R_2}\right) \cdot 4 \Rightarrow \frac{R_1}{R_2} = 2$$

R_1 & R_2 "IN 100's Ω or KΩ's"

Let $R_1 = 5K\Omega$ ⇒ $R_2 = 2.5K\Omega$

For R_3



$$I_s = I_Z = \frac{V_{in} - 4}{R_3} \geq 2mA$$

$$R_3 \leq \frac{V_{in} - 4}{2mA}$$

بالتجريب لقيم V_{in}

$$R_3 \leq \frac{20-4}{2m} = 8K$$

$$R_3 \leq \frac{25-4}{2m} = 10.5K$$

بنختارها لیش؟ لانو لوحطينا 25 وبعدين نزل

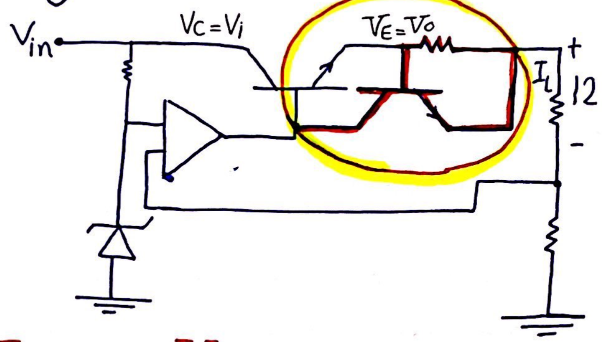
لـ 20 ← $\frac{20-4}{10.5K}$ ← تطلع اقل من 2m لهلئ

الجواب الصح هي [8K]

[1]

Complete "Previous Example"

2- Modify the Circuit to Perform current limit ≤ 1A



$$I_{limit} = \frac{V_{BE2}}{R_{(sc)}}$$

- $R_{(sc)} = \frac{V_{BE2}}{I_{limit}} = \frac{0.7}{1A} = 0.7\Omega$

3- Calculate V_o if [1] $R_L = 100\Omega$ [2] $R_L = 8\Omega$

اذا $I_L < I_{max}$ يصل الـ output = 12

اذا $I_L > I_{max}$ معناته التيار يصير Limited لـ 1A والـ

Output voltage = حاصل ضرب التيار بالمقاومة.

Case 1

Sol. $I_L = \frac{V_o}{100} \Rightarrow \frac{12}{100} = 0.12A < 1A$ ✓

So $V_o = 12 \Rightarrow V_o = \left(1 + \frac{R_1}{R_2}\right) . V_Z$

Case 2

$I_{L2} = \frac{12}{8} \Rightarrow 1.5 > 1A$

$I_{L2} = I_{limit} = 1A$

$V_o = I_L R_L = 1A \times 8\Omega = 8$ volt

نقص

2

Complete "Previous Example"

4 _ Choose BJT with Proper power Rating ?

$P_{BJT} = V_{CE} \cdot I_L$ او I_E ← (the same)

$= (V_i - V_o) \cdot I_L$

$= (25 - 8) \cdot 1A$

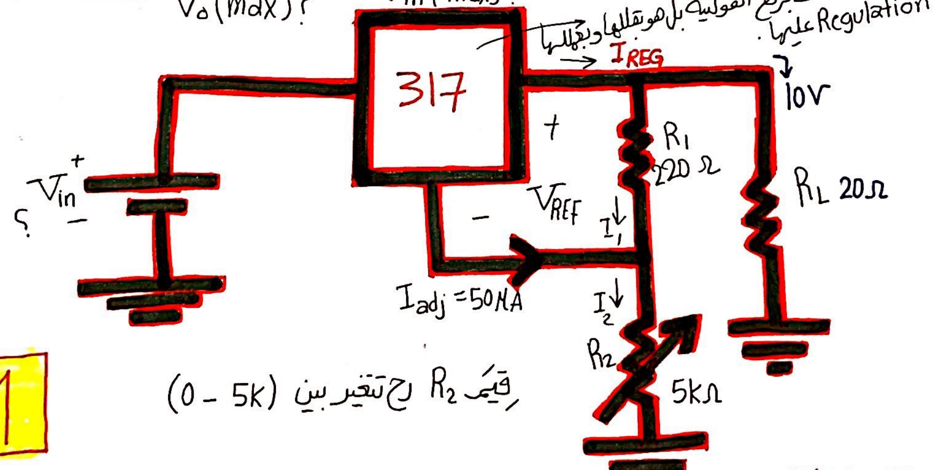
$= 17$ Watt @Current limit mode

Normal Case

Part 2

$V_o(min)$? $V_{in}(min)$?

$V_o(max)$? $V_{in}(max)$?



1 قيم R_2 رح تتغير بين (0 – 5K)

- $V_o(min)\big|_{R_2=0} = V_{REF} = V_{R_1} = 1.25$ Volt / $V_{in}(min) = 3.25\ (1.25 + 2)$ عبارة عن "على الاقل"

- $V_o(max)\big|_{R_2=5k} = V_{R_1} + V_{R_2} \Rightarrow 1.25 + 28.66 = 29.91V$ / $V_i(max) = 31.9V$ على الاقل

$V_{R_2} = I_2 \times R_2$

$= (I_1 + I_{adj}) R_2 = \left(\frac{1.25}{R_1} + I_{adj}\right) R_2$ **3** $= \left(\frac{1.25}{220} + 50\mu\right) \cdot 5K = 28.66V$

Complete Prev. Example

2 Power dissipation

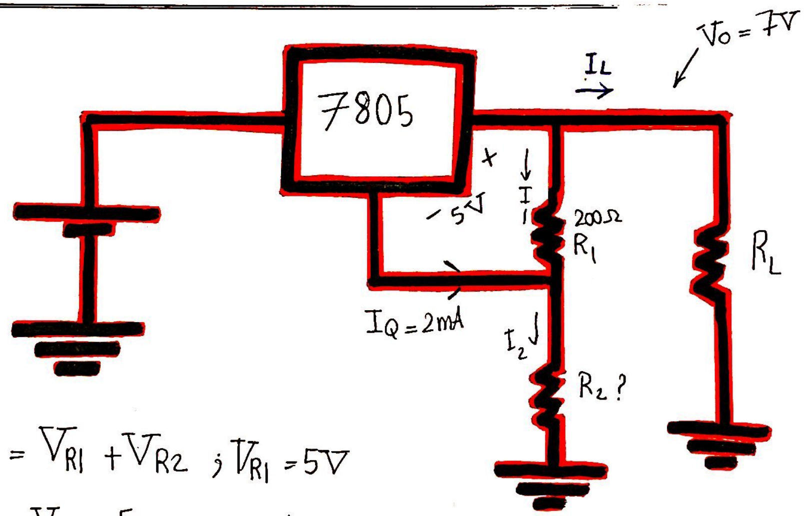
لو الترمنا انو Vin اكبر بـ 2 من Vo

$$P_D = (V_{in} - V_o) \cdot I_{Reg} = 2 \times 0.506 = 1.1 \text{ Watt}$$

$$I_{Reg} = I_1 + I_L$$

$$= 5.6 \text{ mA} + \frac{10}{20}$$

$$= 506 \text{ mA}$$



$$V_o = V_{R1} + V_{R2} \; ; V_{R1} = 5V$$

$$I_{R1} = \frac{V_{R1}}{R_1} = \frac{5}{200} = 25 \text{ mA}$$

$$V_{R2} = (I_Q + I_1) \cdot R_2 = 2$$

$$\therefore R_2 = \frac{2}{(2mA + 25m)} = \frac{2}{27mA} = 74\,\Omega$$

$$P_D = (V_{in} - V_o) \cdot I_{Reg}$$