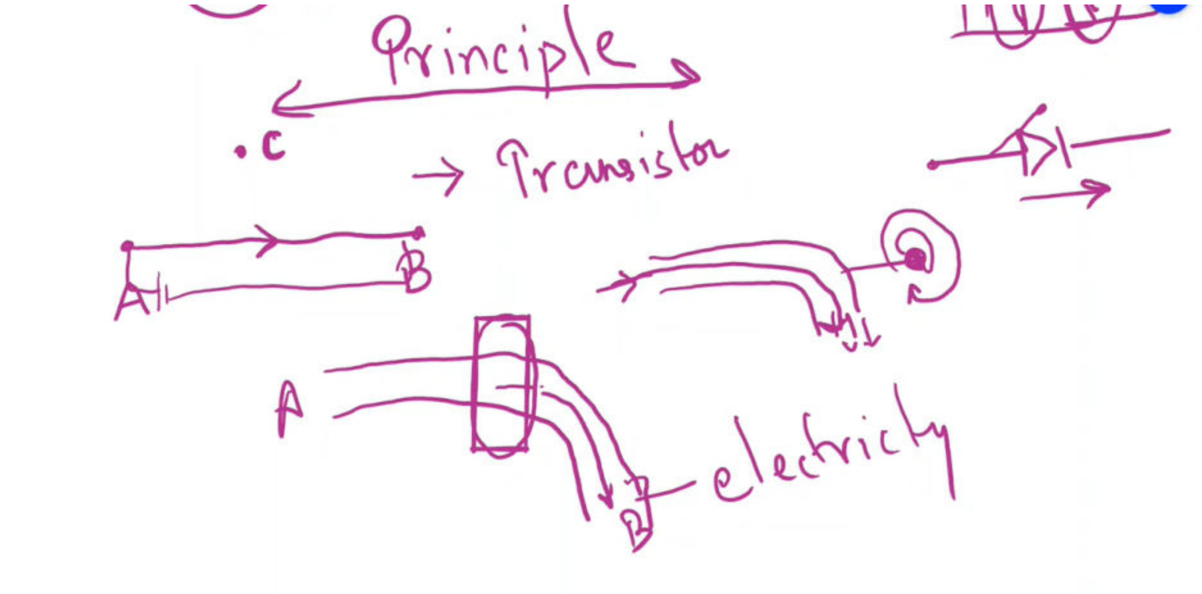
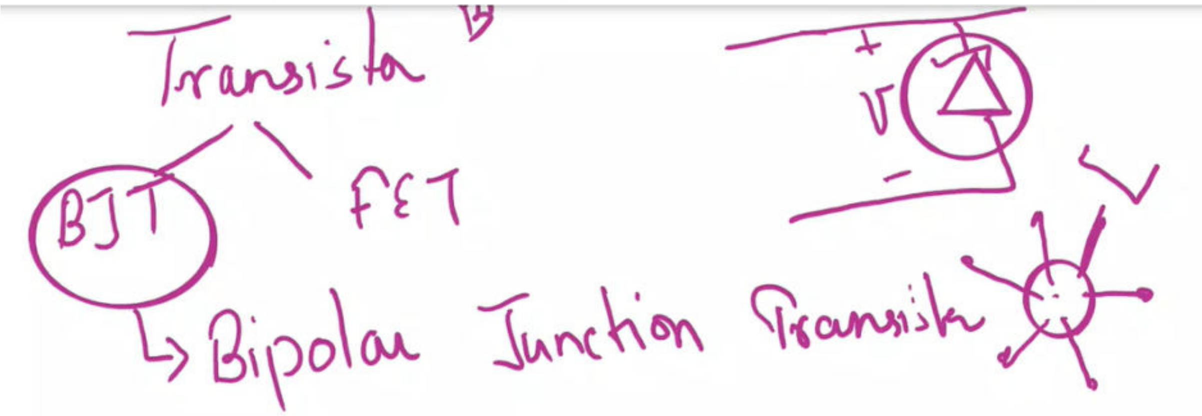
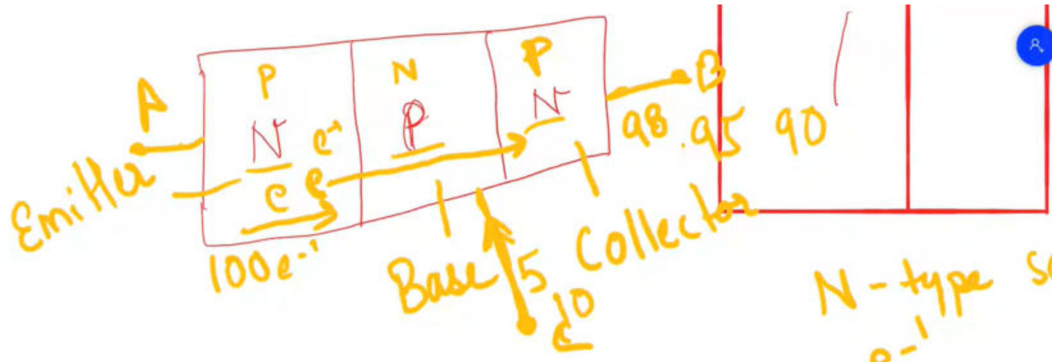
18.10.21

Module 3: Transistors



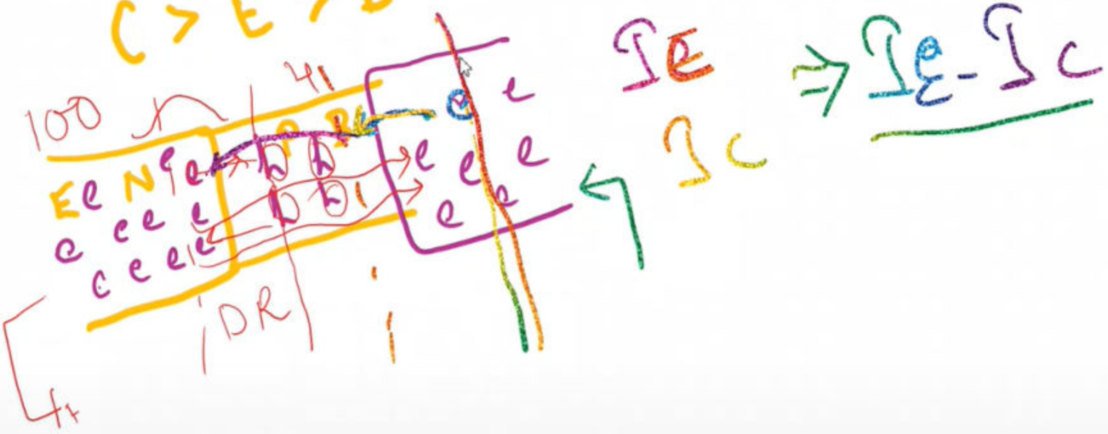


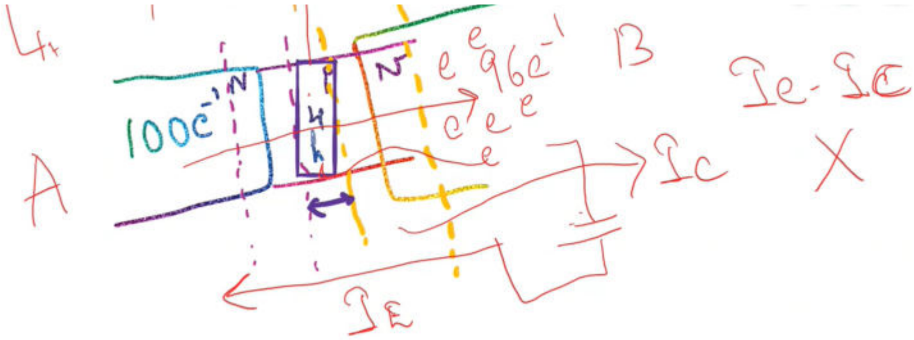


N-type SC →
e^-
P-type SC
– holes

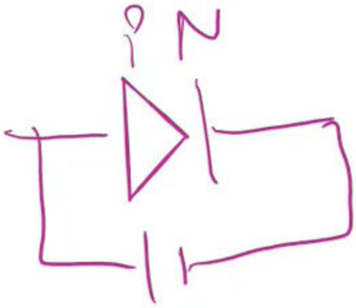
1) Emitter highly doped
2) Base lightly doped
3) Area of base shall be very small
4) " " collector " " " high

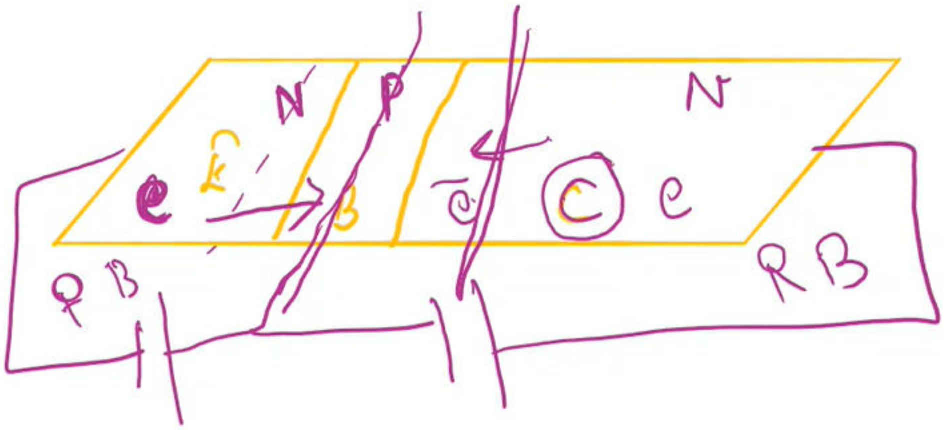
$E > C \cancel{>} B$ DC
$C > E > B$ Area

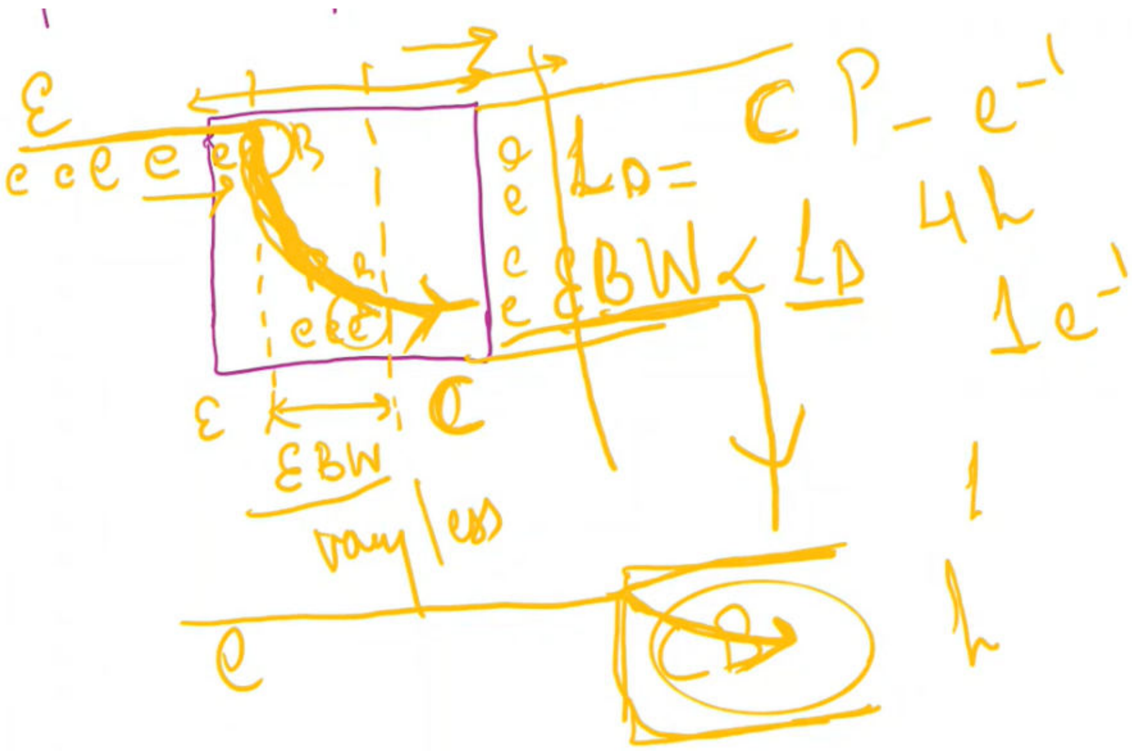


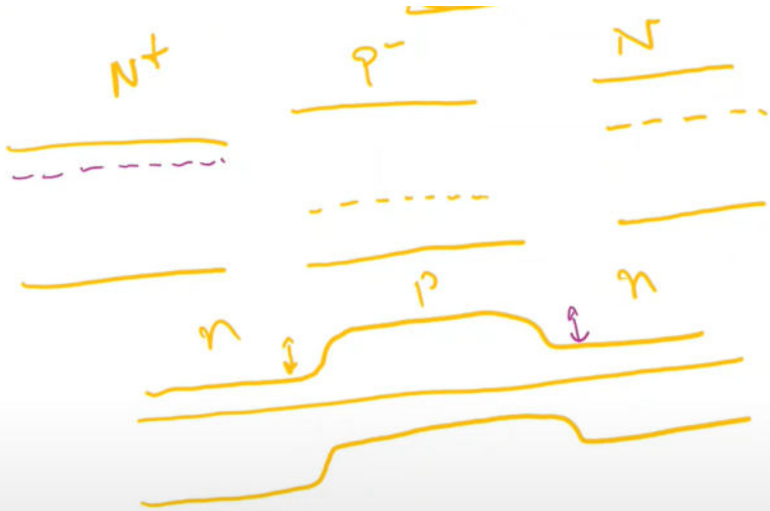


Transistor
Bias







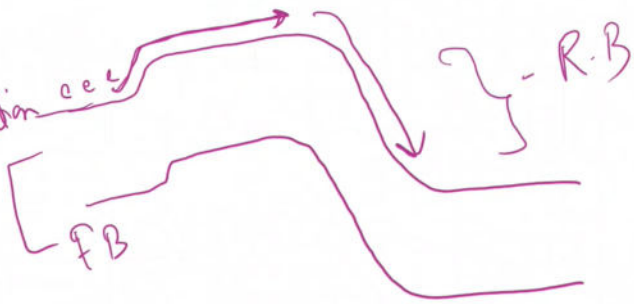


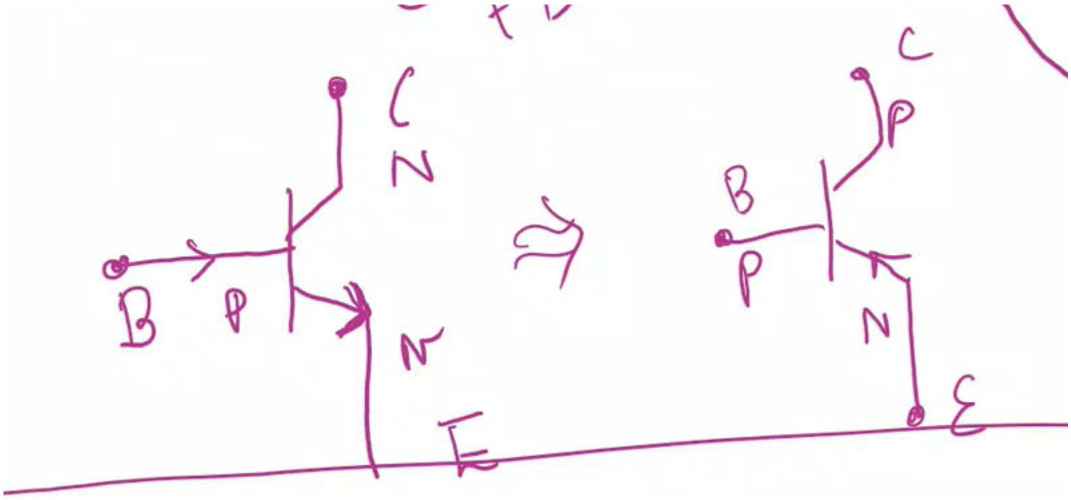
at equilibrium

Transistor

→ BE - FB
→ CB - RB

} - Amplification

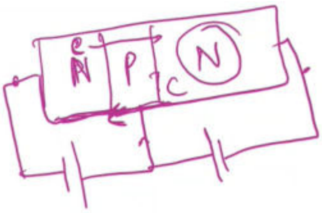




ii) FB, FB

↳ Closed Switch

↳ Saturation Region



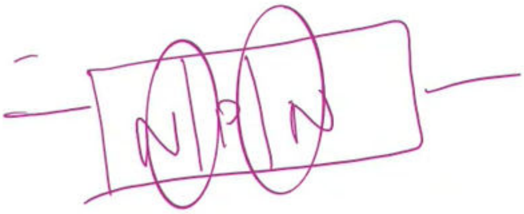
iii) RB, RB → open switch

↳ Cut-off Region

iv) RB, FB

↳ Inverse active Region

Current Component in a Transistor



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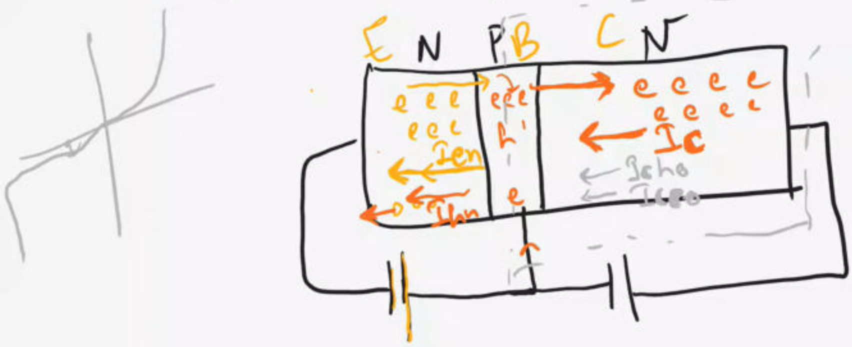
Current Components



EB - FB
CB - RB

$I_E = I_{en} + I_{hn}$

$I_B = I_C$

$I_C = I_c + \boxed{I_{cho} + I_{ceo}}$

$= I_c + I_c$

$I_C = I_c + I_{co}$

I_{co} - V.I $\propto T$

$I_{CEO} = I_{co} \Rightarrow I_{cho} + I_{ceo}$

$I_{co} = I_{co,T_1} \left(2^{\frac{T_2 - T_1}{10}}\right)$

$I_{co} = I_{co}\left(e^{\frac{V_{CB}}{nV_T}} - 1\right)$

1) Emitter Efficiency $\gamma \Rightarrow \dfrac{I_{en}}{I_E} \uparrow \Rightarrow \dfrac{\uparrow I_{en}}{\uparrow I_{en} + I_{hn}\downarrow}$

2) Base Transport factor $B \Rightarrow \dfrac{I_C}{I_{en}}$

I_{CO} - very

3) Large Current Gain $\alpha = \dfrac{I_C}{I_E}$

I_{CO} - very small

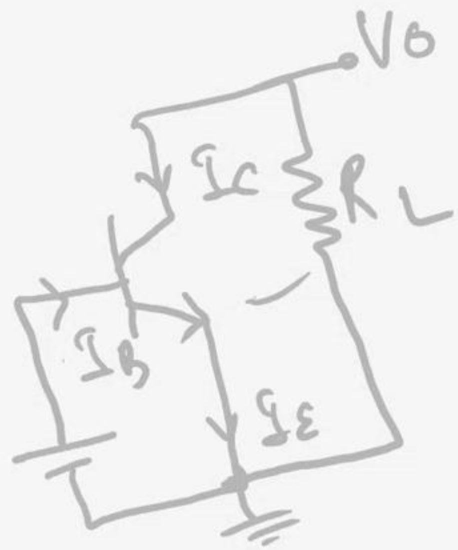
I_E

Common Base

Common Emitter

Common Collector

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



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

$$I_E = I_B + I_C$$

$$I_C = I_c + I_{CO}$$

$$\alpha = \frac{I_C}{I_B + I_C} \Rightarrow \frac{\beta I_B}{I_B + \beta I_B}$$

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

$$\boxed{\alpha = \beta / 1+\beta}$$

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

$$\boxed{I_{CEO} = \frac{I_{CBO}}{1-\alpha}}$$

1) α (current am. factor) Given

$\alpha = 0.988$ I_{CO}

$I_B = ?$ if $I_E = 1.2\,mA$

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

$$= 0.988 \times 1.2$$

$$= \underline{\underline{1.1856\,mA}}$$

$$I_B = I_E - I_C$$

$$1.2 - 1.1856$$

$$= 0.0144\,ml$$

2) $I_B = 45\,\mu A$, I_C, $5.45\,mA$

(I) $\underline{\alpha, \beta, I_E}$

(II) $I_B \rightarrow I_C = 10\,mA$

* For any tran $\underline{\alpha, \beta}$ will be T

Answer:

$$I_E = I_B + I_C$$

$$= 45\mu + 5.45 = \underline{\underline{5.495\,mA}}$$

$$\alpha = \frac{I_C}{I_E} = \frac{5.45}{5.495} = \underline{\underline{0.9918}}$$

$$\beta = \frac{I_C}{I_B} = \frac{\alpha}{1-\alpha} = \frac{5.45 \times \cancel{10^{-3}}\times 10^{3}}{45 \times 10^{-6}} = \underline{\underline{121}}$$

$I_B \Rightarrow \quad I_C = 10\,mA$

$$I_C = \beta I_B$$

$$I_B = \frac{I_C}{\beta} = \frac{10 \times 10^{-3}}{121}$$

$$= \underline{\underline{82.6\,\mu A}}$$

3) In a CB, $I_E = 1.6\,mA$, $I_{CEO} = 10\,\mu A$, $I_C = ?$, $\alpha = 0.98$ $\Rightarrow$ $I_C = I_C + I_{CEO}$

$\hookrightarrow \alpha I_E$

$I_C = 0.98 \times 1.6 + 10\mu$

$= \underline{1.57\,mA}$

4) In a CE, $I_E = 5mA$, $I_C = 4.95$

$I_{CEO} = 200\,\mu A$, Find β & I_{CBO}

$$I_{CEO} = \frac{I_{CBO}}{1-\alpha}$$

α, β $\quad\quad \beta = \frac{I_C}{I_B}$, $\alpha = \frac{I_C}{I_E}$

$I_{CBO} = (1-\alpha) I_{CEO}$ $\quad \beta = \frac{\alpha}{1-\alpha}$ $\quad \alpha = \frac{4.95}{5}$

$= (1-0.99)200\,\mu$ $\quad = \frac{0.99}{1-0.99} = \underline{\underline{99}}$ $\quad = \underline{\underline{0.99}}$

$= \underline{\underline{2\,\mu A}}$

$$I_E = I_B + I_C$$

$$5 - 4.95 = I_B = 0.05\,mA$$

$$\beta = \frac{I_C}{I_B} = \frac{4.95}{0.05} = \underline{\underline{99}}$$

$$\alpha = \frac{\beta}{1+\beta} = \frac{99}{1+99} = \underline{\underline{0.99}}$$

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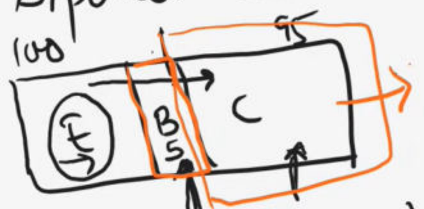
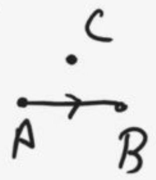
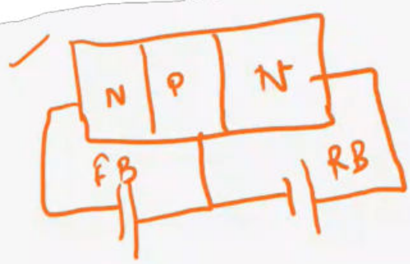
BJT → Bipolar Junction Transistor





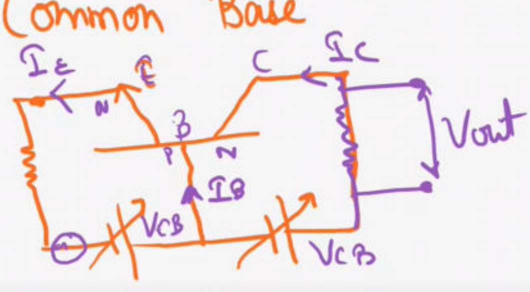
$$I_E = I_C + I_B$$



Configuration of Tr:

* Common Base
* Common Emitter
* Common Collector

1) Common Base



$$\frac{I_C}{I_E} = \alpha_{dc}\ ,\ \alpha_{ac}$$

I_{CO} $\quad \alpha_{dc} = \dfrac{I_C - I_{CO}}{I_E}$

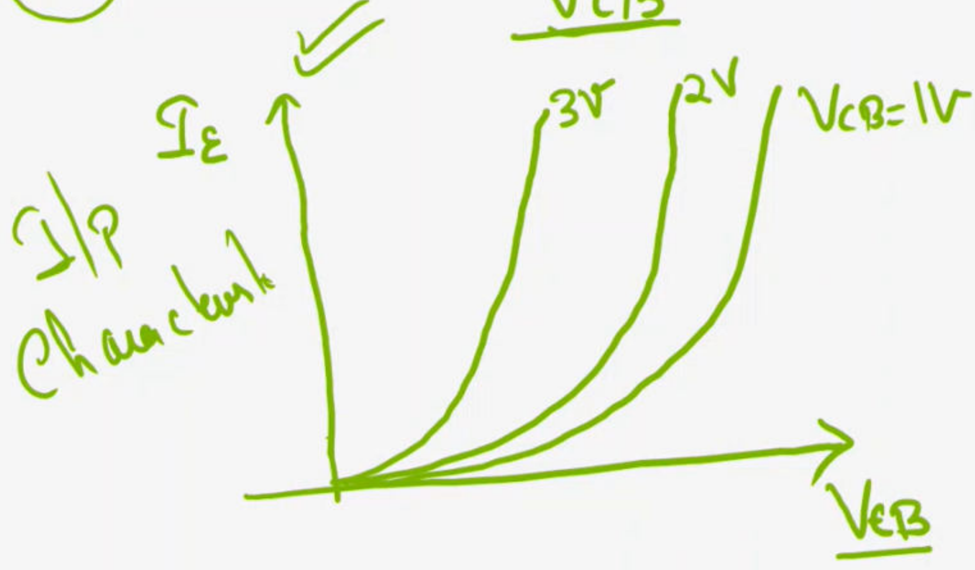
* Characteristic of CB Configuration

I/p — I/p current wrt to i/p voltage

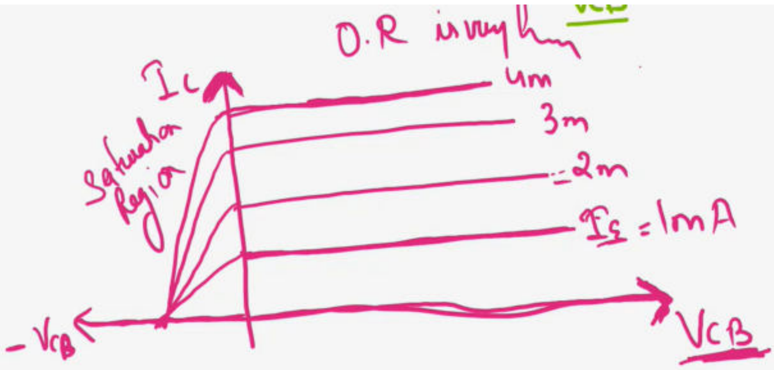
O/p

I_C Vs V_{CB} for a given value of I_E -> o/p

$I_E = I_C + I_B$ ← I_E Vs V_{EB} for a given V_{CB}



resistance of B-E junction

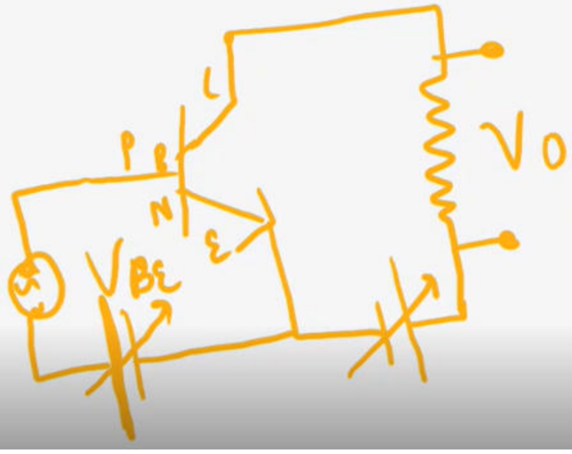


I_C is α I_E

$\frac{I_C}{I_E} \approx 1$

1) Early ~~width~~ Effect or Base Width modulation effect

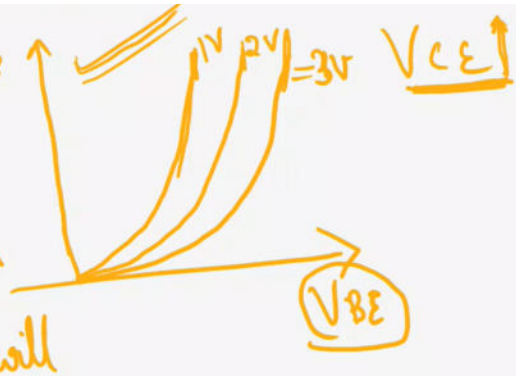
2) Common Emitter



I/p Charactr → I_B

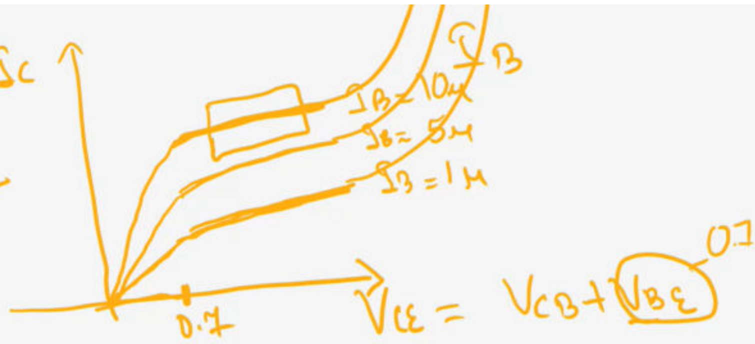
$\uparrow V_{CE} = \uparrow V_{CB} \pm V_{BE}$

$V_{CB}\uparrow$ BW will reduce



O/p Characteristic

$\uparrow I_C = \beta I_B \uparrow$



OR - high
IR - Medium
CG - $\frac{I_C}{I_B}$ - very high
VG - moderate
Amplifier

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

amp. CB E is open

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

$I_E = I_B + I_C$

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

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

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CE

$I_C = \frac{\alpha I_B}{1-\alpha} + \frac{I_{CBO}}{1-\alpha} \Rightarrow I_{CEO}$ β

β CE

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

CE $\boxed{I_C = \beta I_B + I_{CEO}}$

$\frac{\alpha}{1-\alpha} = \beta \Rightarrow \frac{1}{1-\alpha} = 1+\beta$

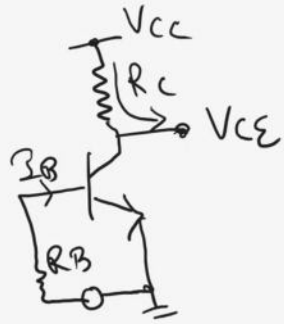
2) fin a rela α, β

I_{CBO}, I_{CEO}

I_C, I_{CEO}

1) $V_{CC} = 10V$ $R_C = 1k$, $V_{R_C} = 0.5V$ $\alpha = 0.98$

V_{CE} & I_B



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

$= 10 - 0.5V = 9.5V$

$\beta I_B = I_C$

$I_C R_C = 0.5$

$I_C = 0.5/1k = 0.5$ mA

$\alpha = 0.98$ $\quad \beta = \frac{0.98}{1-0.98} = 49$

$I_B = \frac{0.5}{49} \simeq \underline{\underline{10.2 \mu A}}$

2) CE

$I_C = 5mA$, $I_B = 50\mu A$, $I_{CBO} = 1\mu A$

1) α, β, I_E

2) find I_B corresponding to $I_C = 10mA$

$$\beta = \frac{I_C - I_{CBO}}{I_B + I_{CBO}} = \frac{5\times10^{-3} - 1\times10^{-6}}{50\times10^{-6} + 1\times10^{-6}}$$

$$\Rightarrow \frac{10^{-3}}{10^{-6}}\left[\frac{1 - 10^{-3}}{51}\right]$$

$$10^{+3}\left[1/51\right] = 0.098$$

$$\simeq 98$$

$\alpha = \beta/_{\beta+1} = \frac{98}{99} = \underline{\underline{0.99}}$ 10

$I_E = I_B + I_C = (5 + 50 \times 10^{-3})$ mA

$\underline{\underline{5.05 mA}}$

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

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

$= 101 \mu A$

BJT

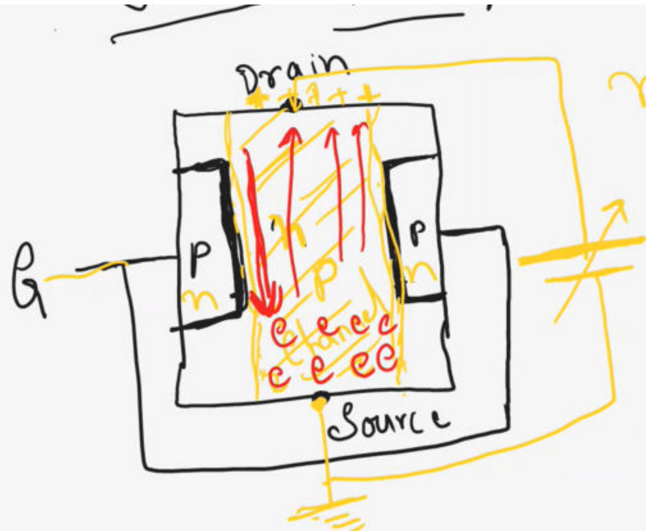
- noisy ✓
- large area
- low gain
- high Power dissipation
- high leakage current
- low switching activity

FET- field effect transistor

junction

JFET MOSFET

A B C

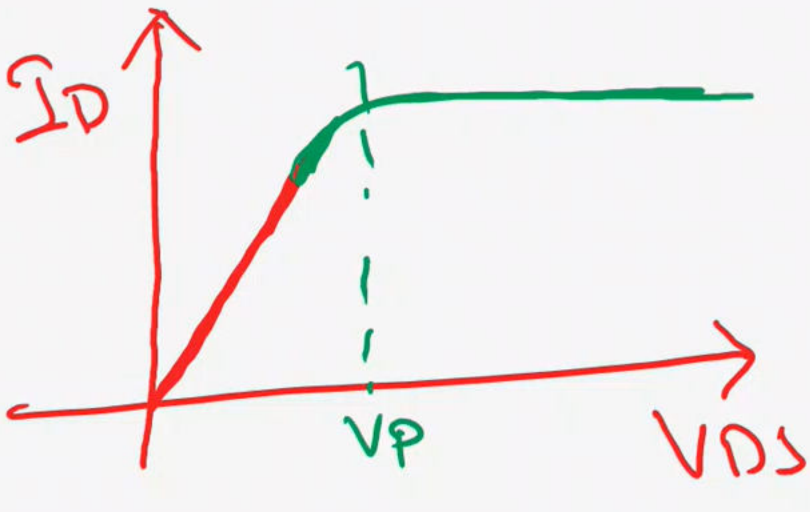


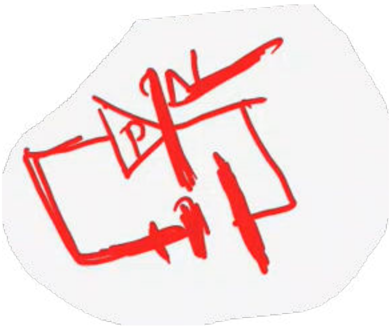
n-channel JFET

p-channel JFET

I_D – D to S

I_D – D to S




P
N

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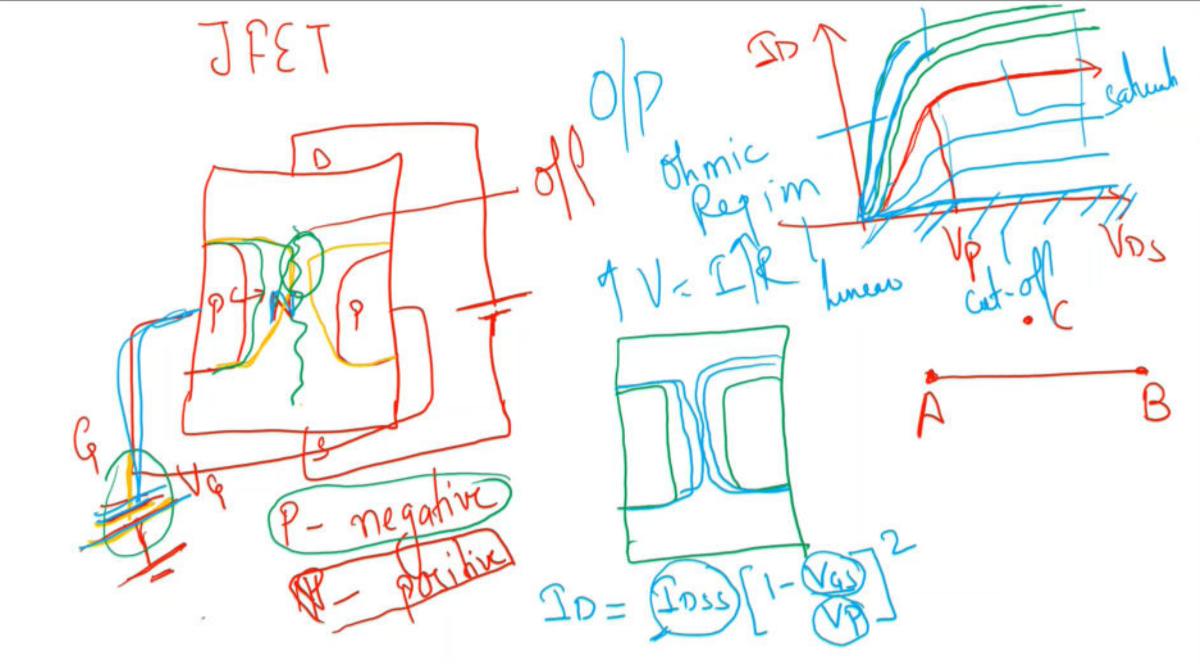
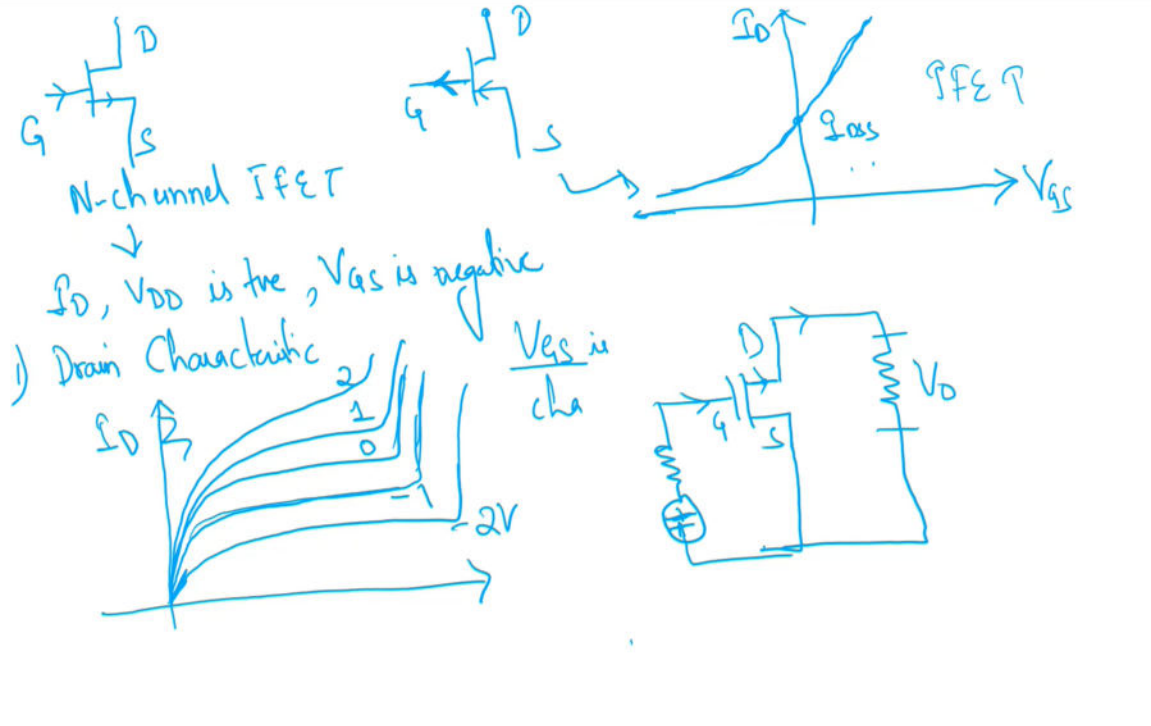
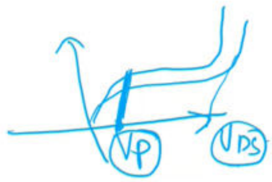

JFET
o/p
O/P
D
P
N
P
S
G
V_G
P - negative
N - positive
Ohmic Region
↑V = I↑R
linear
I_D
V_P
V_{DS}
cut-off
saturation
C
A
B
$I_D = I_{DSS}\left[1 - \frac{V_{GS}}{V_P}\right]^2$


D
G
S
N-channel JFET
I_D, V_{DD} is +ve, V_{GS} is negative
1) Drain Characteristic
I_D
2
1
0
-1
-2V
V_{GS} is cha
D
G
S
I_D
I_{DSS}
V_{GS}
JFET
V_D

V_{DS} NJFET to pinch off condition

$\beta = \frac{I_C}{I_B}$ $V_{GS} = 1V$, $V_p = -2V$, $I_{DSS} = 10mA$, I_D



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

$= 10\left(1 + \frac{1}{2}\right)^2$

$10 \times \frac{3}{2} \times \frac{3}{2} = \frac{45}{2} = \underline{22.5mA}$

$V_{GS} \rightarrow I_D$ Transconductance $- \frac{\partial I_D}{\partial V_{GS}}$

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

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

g_{mo}

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

Amplification factor

$\mu = \frac{\Delta V_{DS}}{\Delta V_{GS}} = \frac{\Delta V_{DS}}{\Delta I_D} \times \frac{\Delta I_D}{\Delta V_{GS}} \Rightarrow \boxed{g_m \times r_d}$

$V_p = -4.5V$, $I_{DSS} = 9mA$, $\underline{I_{DS} = 3mA}$, g_m at $I_{DS} = 3mA$

$V_{GS} = ?$

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

$= \underline{-1.902V}$

$g_m = -\frac{2I_{DSS}}{V_P}\left(1 - \frac{V_{GS}}{V_P}\right) = \underline{2.31\ mA/V}$ or mS

lab Module 4 → CE amp
40 ← MOSFET

JFET

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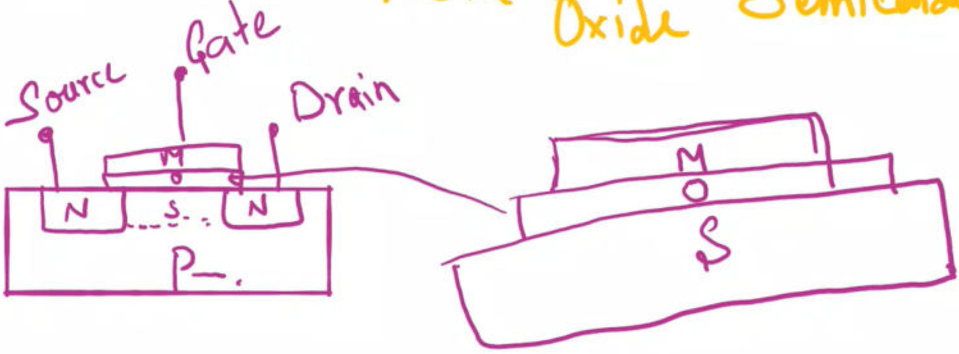
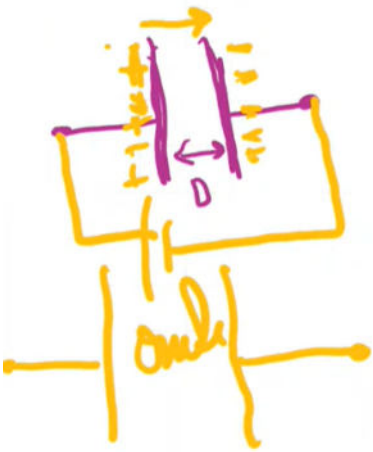
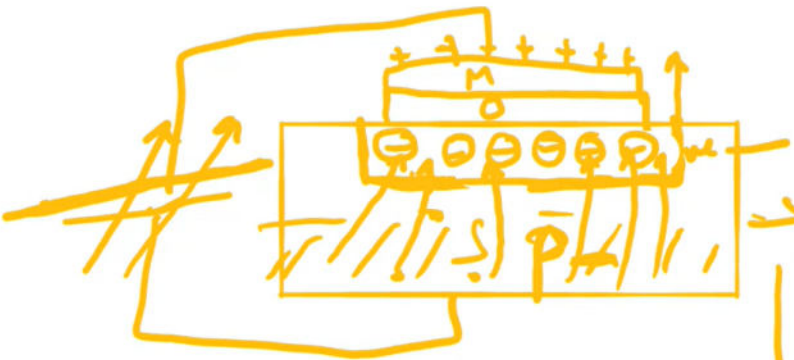
MOSFET

Metal Oxide Semiconductor





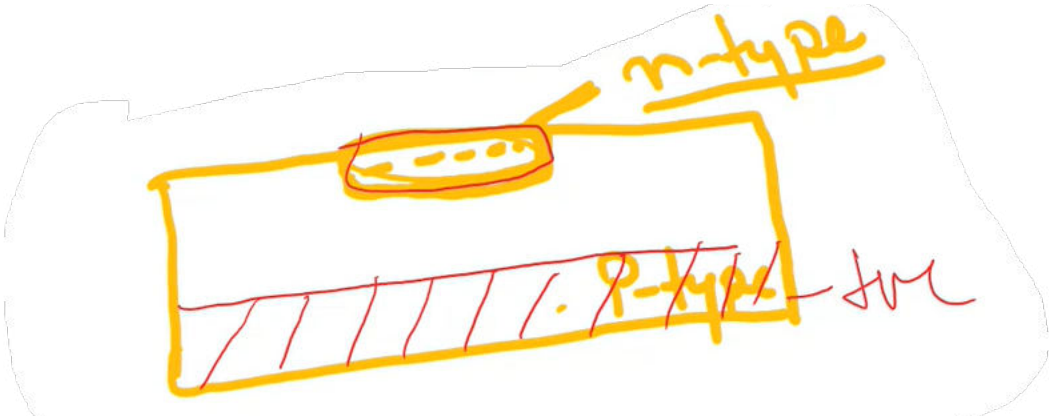


Accumulation

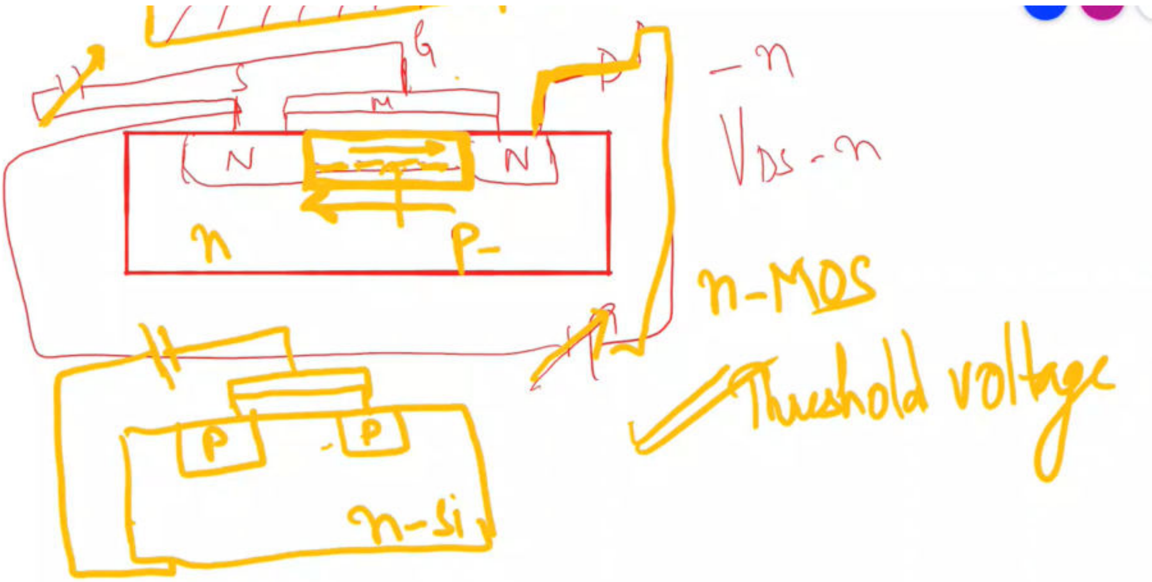
→ Depletion

⊖ ⊖ ⊖

→ Inversion

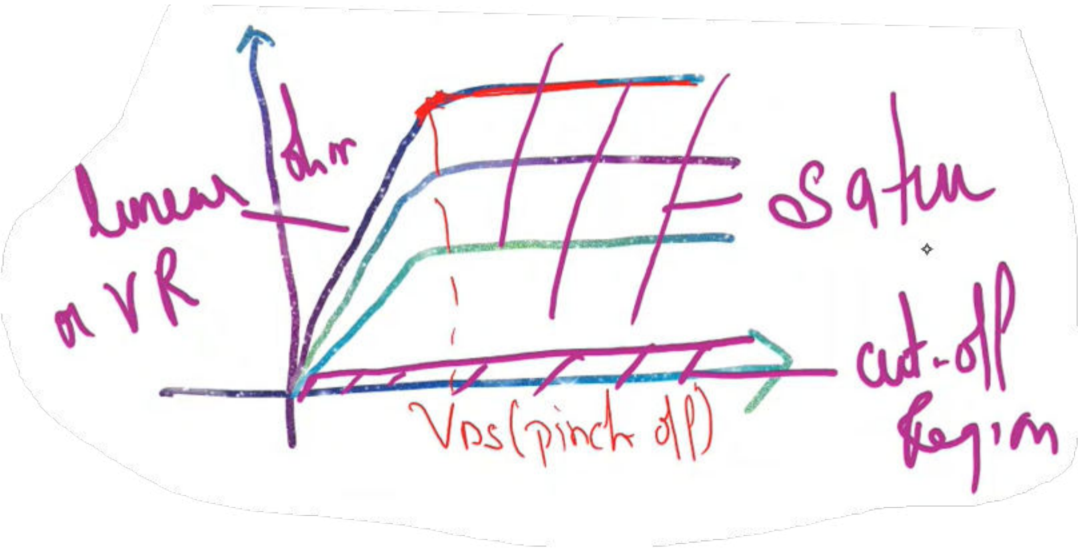


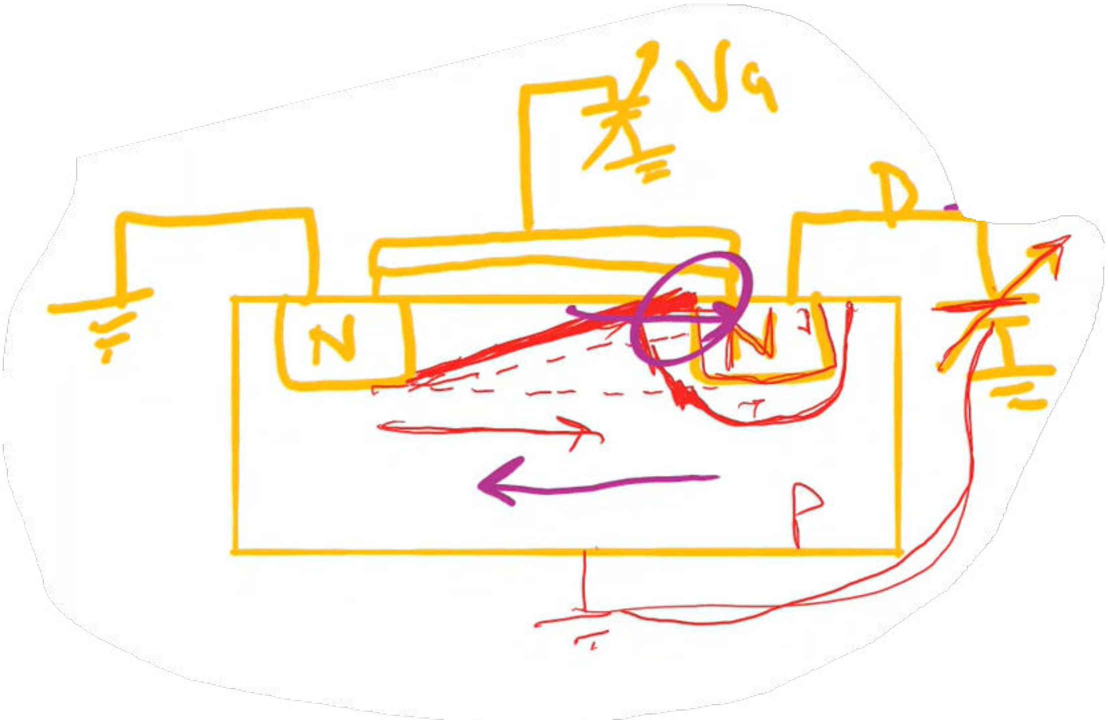
n-type
P-type



G
S
M
D
N
N
n
P-
n-Si
P
P
- n
VDS - n
n-MOS
Threshold voltage

ID
JFET
Mosfet
IDSS
VGS
VGS Threshold
ΔVGS
ΔID

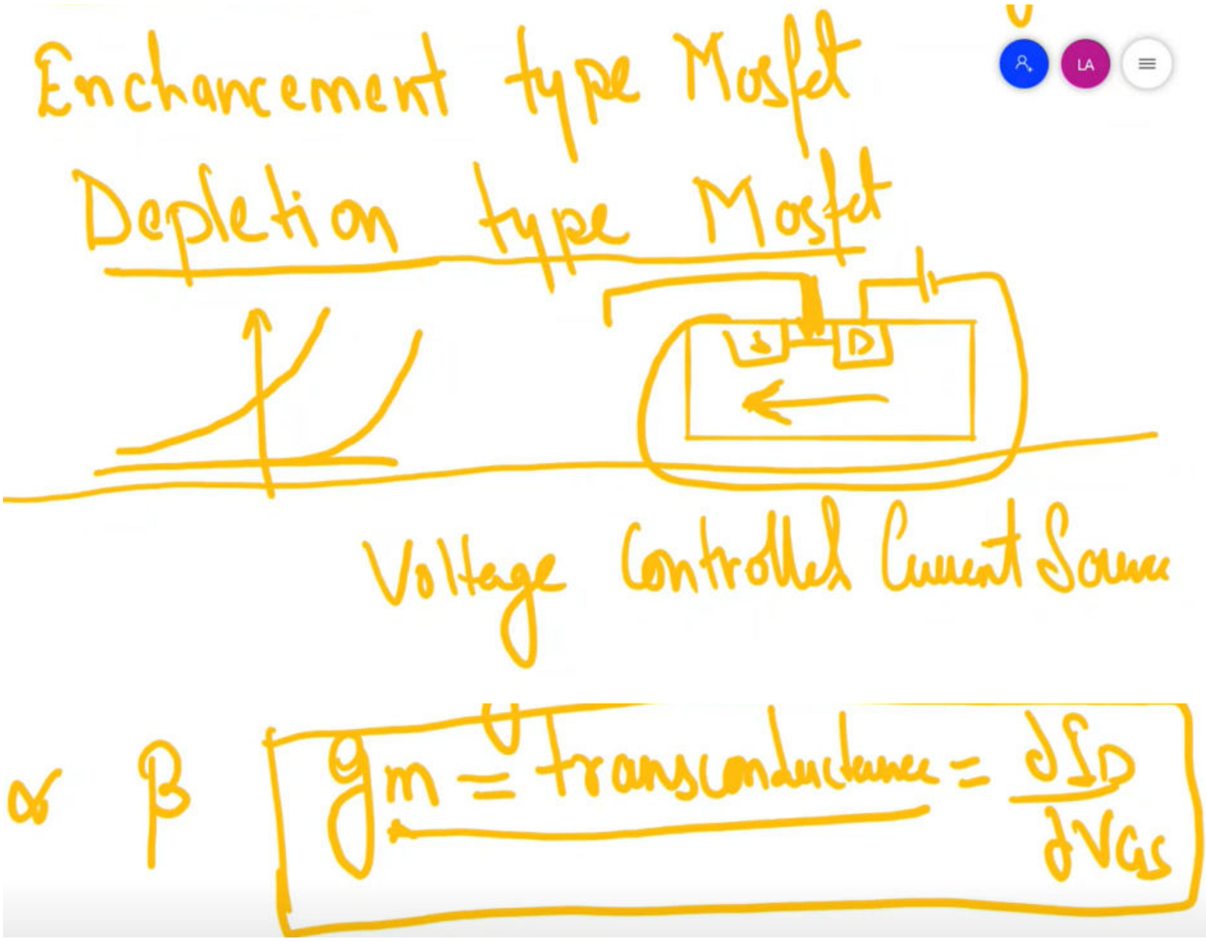




$$I_D = K'n\, C_{ox} \frac{W}{L}\left[(V_{GS}-V_{th})V_{DS} - \frac{V_{DS}^2}{2}\right]$$ — linear Region
ohmic Region

$$I_D = K'n\, C_{ox} \frac{W}{L}(V_{GS}-V_{th})^2 \rightarrow$$ Saturation Region

$$\boxed{V_{DS} \geq V_{GS}-V_{th}}$$ — Saturation Region



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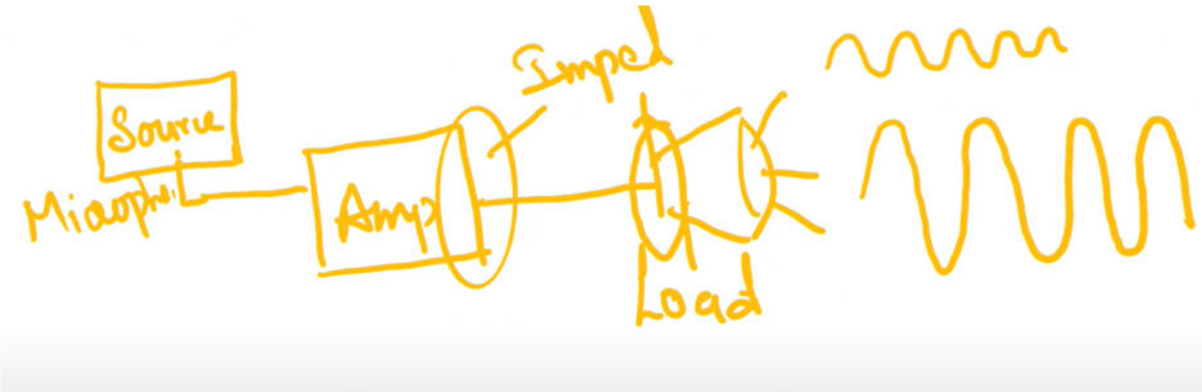
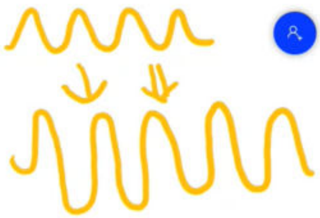
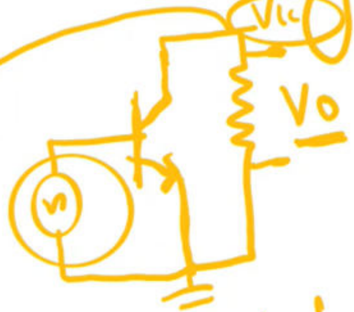
<u>Module 4: Transistor as an amplifier</u>



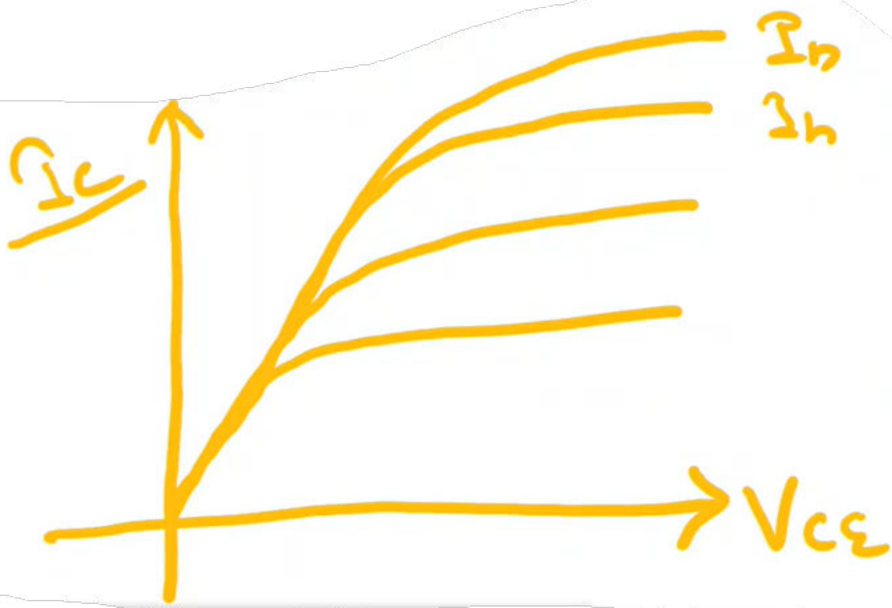
a.c signal –





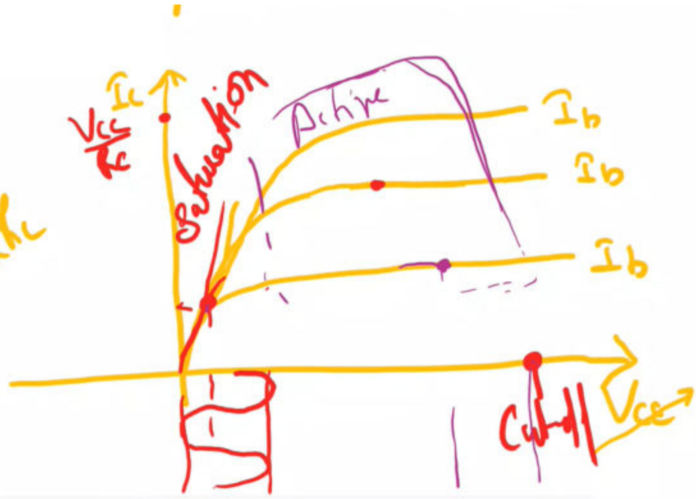
a.c at o/p
⇓
i/p ac + dc power

Biasing conditions



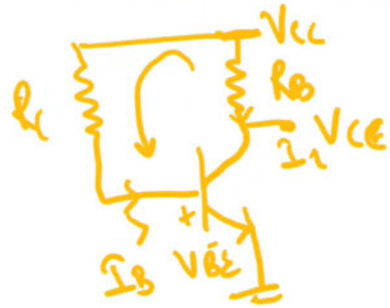
$V_{CE} = V_{CC} - I_C R_C$

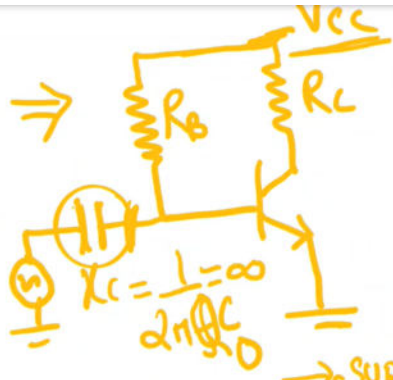
~~(V_{CE}, I_C)~~



Fixed Bias Technique ⇒

V_{CEQ} , I_{CQ}

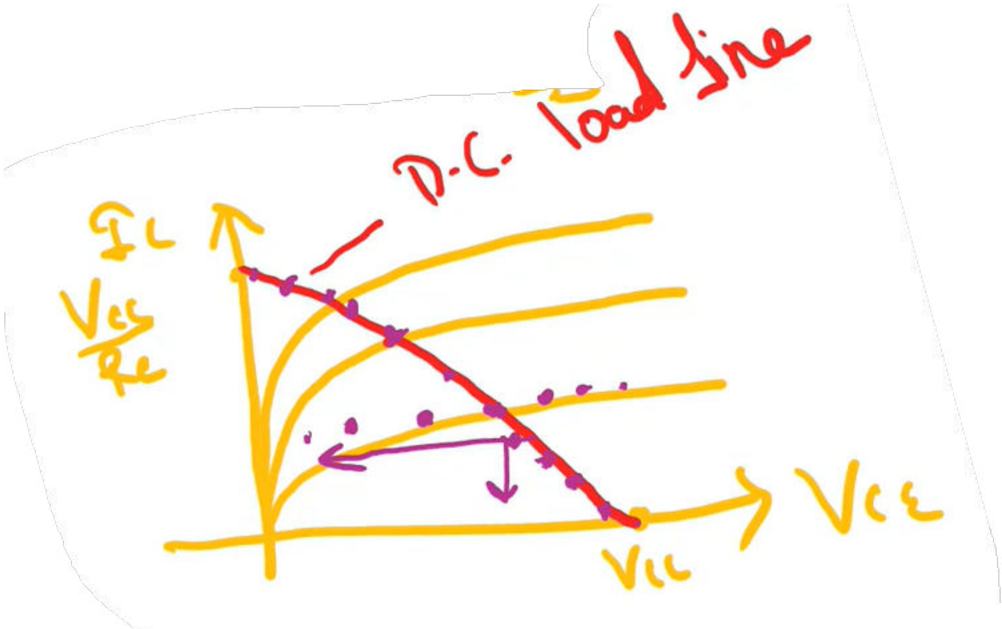




i_c

v_{ce}

→ superposition theorem



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

$$\boxed{I_B = \frac{V_{CC} - V_{BE}}{R_B}} \qquad \boxed{I_C = \beta I_B}$$

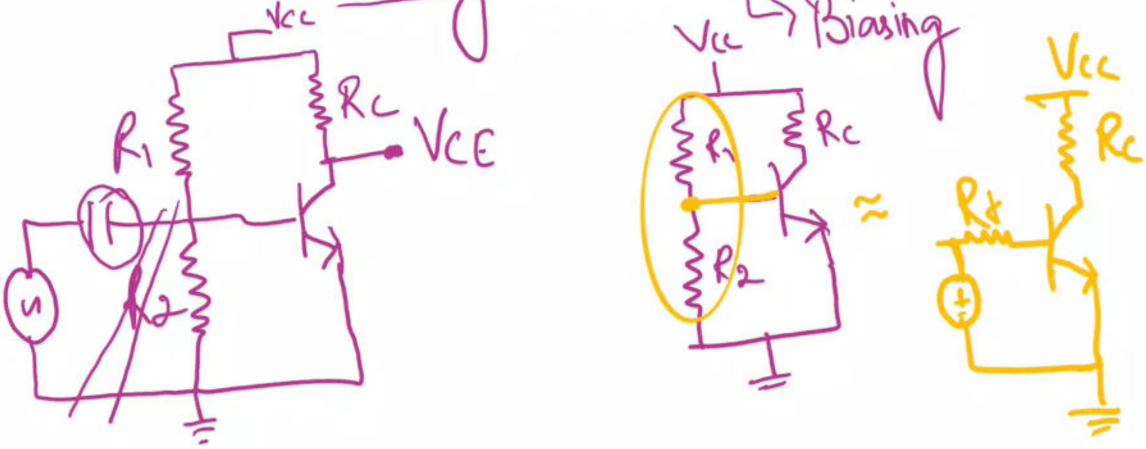
$$V_{CC} = I_C R_C + V_{CE}$$

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

$$\boxed{V_{CE} = \frac{V_{CC}}{2}}$$

Stability:

↳ Voltage Divider Circuit ↳ Biasing



$$R_{th} = R_1 \parallel R_2$$

$$V_{th} = \frac{V_{cc} \times R_2}{R_1 + R_2}$$

Q-point

V_{CE}, I_C

$$V_{th} = I_B R_{th} + V_{BE}$$

$$\frac{V_{th} - V_{BE}}{R_{th}} = I_B$$

$$I_C = \beta I_B$$

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

$$V_{th} = I_B R_{th} + V_{BE} + \underline{I_E} R_E$$

$$V_{th} - V_{BE} = I_B R_{th} + (I_B + \underbrace{I_C}_{\beta I_B}) R_E$$

$$V_{th} - V_{BE} = I_B R_{th} + I_B(\beta+1) R_E$$

$$\boxed{I_B = \frac{V_{th} - V_{BE}}{R_{th} + (\beta+1) R_E}}$$

Voltage Divider with emitter Resistance

$$I_C = \beta I_B$$

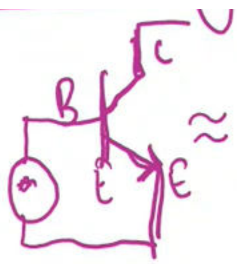
$$V_{CC} = V_{CE} + I_C R_C + I_E R_E$$

$$\boxed{V_{CE} = V_{CC} - I_C R_C - I_E R_E}$$

2.12.21 – class cancelled due to internet problems

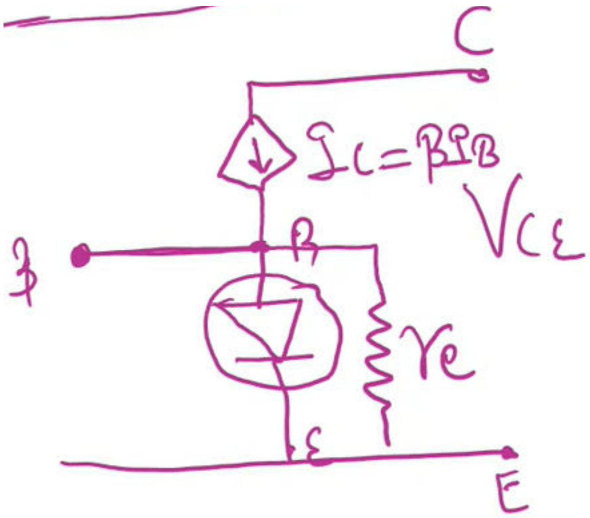
3.12.21

a.c. analysis of transistor

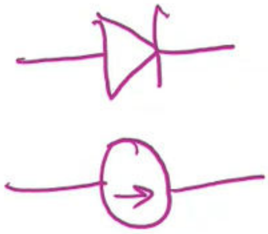


Operating

$$\boxed{V_{CE} \approx \frac{V_{CC}}{2}}$$



$\approx$



$$r_e = \frac{V_T}{I_E} = \frac{26mV}{I_E}$$

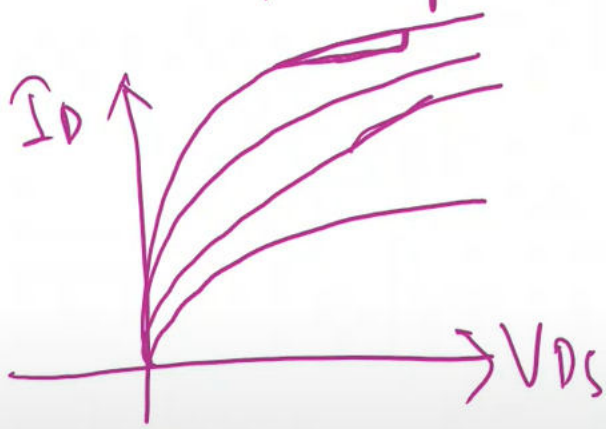
$$V_{be} = I_e r_e$$

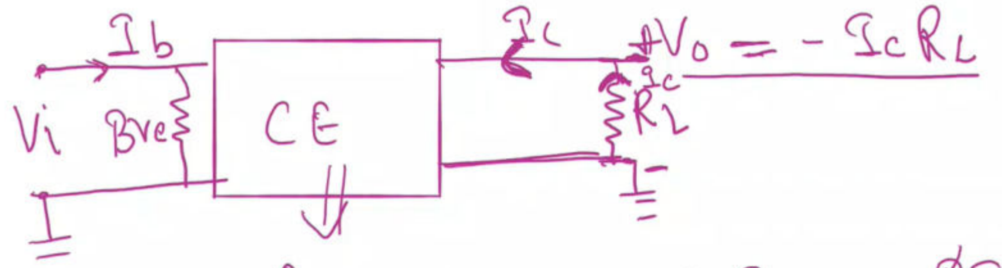
$$Z_i = \frac{V_i}{I_i} = \frac{V_{be}}{I_b} = \frac{(\beta+1) I_b r_e}{I}$$

$$I_e = I_c + I_b \Rightarrow \beta I_b + I_b = I_b(\beta+1)$$

$$\boxed{Z_i = (\beta+1) r_e}$$

$$Z_o \approx r_o \Rightarrow \frac{1}{slope}$$

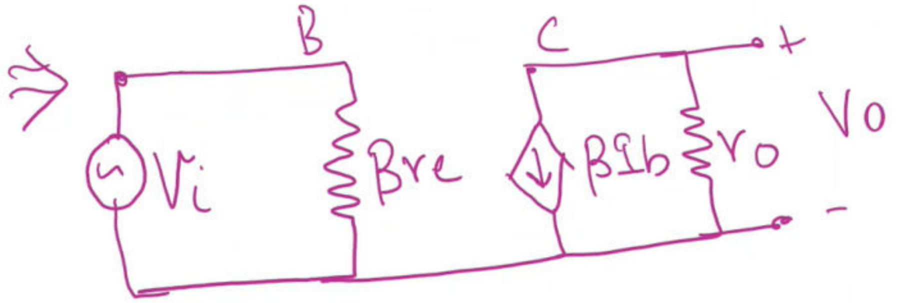




$$A \Rightarrow \frac{V_o}{V_i} = \frac{-I_c R_L}{I_i Z_i} = \frac{-\cancel{\beta}\cancel{I_b} R_L}{\cancel{I_b}\cancel{\beta} r_e}$$

$$\boxed{A = -\frac{R_L}{r_e}}$$

$$\boxed{A = -\frac{R_L}{r_e}} = \frac{-R_L I_E}{V_T} \qquad r_e = \frac{V_T}{I_E}$$



AC- equivalent re model of CE amp

① $\beta = 120$, $I_E = 3.2mA$ $r_o = \infty$

1) Z_i

2) A_v if a load of $2k\Omega$ is applied

3) A_i

1.1)

$$r_e = \frac{V_T}{I_E} = \frac{26m}{3.2m} = \underline{\underline{8.125\Omega}}$$

1.2)

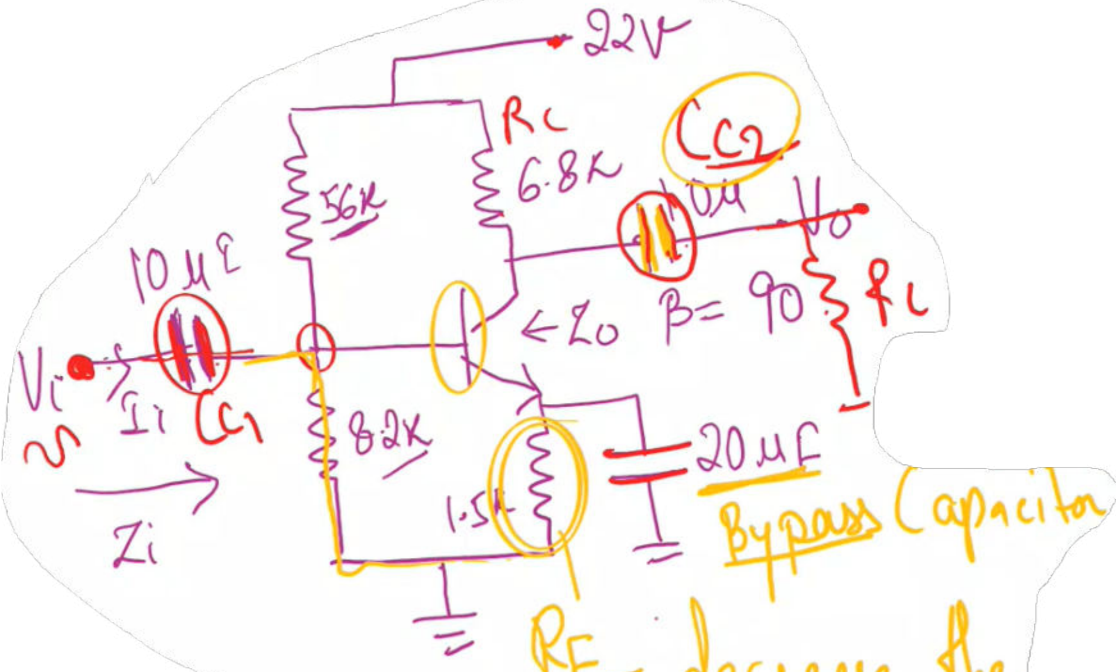
$$A_v = -\frac{R_L}{r_e} = \frac{-2000}{8.125} =$$

$$A_v = -246.15$$

1.3)

$$A_i = \frac{I_o}{I_i} = \boxed{\frac{I_c}{I_b} \simeq \beta} \simeq \underline{\underline{120}}$$

2)R-C coupled CE amplifier



R_E - decrease the gain

$$A_V = -\frac{R_C}{r_e}$$

$$\boxed{= -\frac{R_L \| R_C}{r_e + R_E}}$$

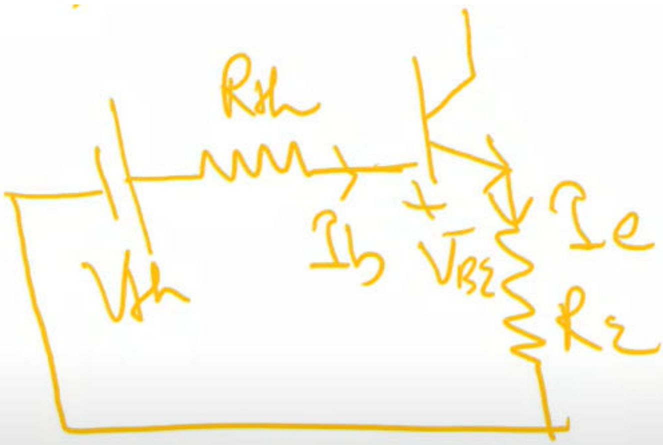
C - DC - open circuit

$$X_C = \frac{1}{2\pi f C} = \frac{\infty}{0}$$

$$X_C = \frac{1}{2\pi f C} \approx 0$$

1) r_e
2) Z_i
3) $Z_o\ (r_o = \infty)$
4) $A_v\ (r_o = \infty)$

$$r_e = \frac{V_T}{I_E}$$



$$V_{th} = I_b R_{th} + V_{be} + I_e R_e$$

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

$$R_{th} = R_1 \| R_2$$

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

$$R_{th} = R_1 \| R_2$$

I_b

$R_{th} = R_1 \| R_2 =$

$V_{BE} = V_B - V_E$

$V_E = V_B - V_{BE}$

$V_E = 2.8 - 0.7 = \underline{2.1V}$

$V_E = I_E R_E = \frac{2.1}{1.5} = \cancel{18.44} = 1.41mA$

$r_e = \frac{V_T}{1.41} = \frac{26}{1.41} = 18.44$

$Z_i = R_1 \| R_2 \| \beta R_e$

$= 56k \| 8.2k \| 90 \times 18.44$

$\frac{R_1 R_2 R_3}{R_1 + R_2 + R_3}$

$Z_i = \underline{1.35K}\ \Omega$

$\frac{R_1 R_2}{R_1 + R_2}$

$Z_0 = R_C = 6.8K\Omega$

$R_c \| R_L$

$$A_V = -\frac{R_C}{r_e} \approx -\frac{6.8k}{18.44} = \underline{\underline{-368.76}}$$

OSCILLATOR

INTRODUCTION

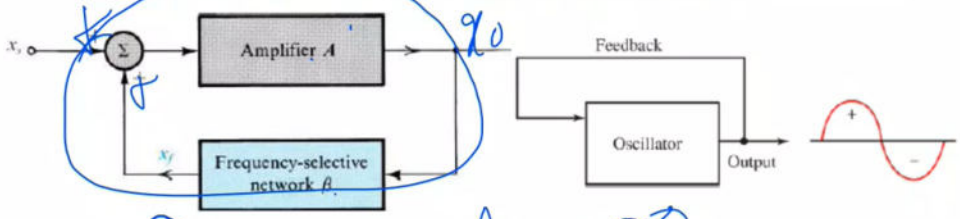
- ***convert dc energy to ac energy at a very high frequency***.
- If the feedback signal is ***large enough and has correct phase***, there will be an output signal even though there is ***no external input signal***.
- The criterion is that the ***signal fed back to the input of the amplifier*** must be ***in phase***. In-phase feedback is also called **positive feedback**, or regenerative feedback.
- It is an ***unstable amplifier***.

- Electronic oscillators are divided into:
  - ***Sinusoidal*** (or ***harmonic***) oscillators-which produce an output having sine waveform
  - ***Non-sinusoidal*** (or ***relaxation***) oscillator-the output is square, rectangular or saw-tooth or pulse shape.

- Oscillators are widely applied in many digital devices, Signal generator, Touch-tone telephone, musical instrument and radio/television transmitter and etc.

The Oscillator Feedback Loop

A basic structure of a sinusoidal oscillator consists of an amplifier and a frequency-selective network connected in a positive-feedback loop.



$$A_f(s) \equiv \frac{x_o}{x_i} = \frac{A(s)}{1 - A(s)\beta(s)} = \frac{A}{1-A\beta} = \infty \qquad L(s) \equiv A(s)\beta(s)$$

The condition for the feedback loop to provide sinusoidal oscillations of frequency w_0 is

$$L(j\omega_0) \equiv A(j\omega_0)\beta(j\omega_0) = 1 \qquad A\beta = 1$$

Barkhausen Criterion:

1. At w_o the phase of the loop gain should be zero.
2. At w_o the magnitude of the loop gain should be unity.

Barkhausen criterion : fa oscillation

$A\beta \geq 1$

- The feedback factor or loop gain . The gain is infinite, this represent the condition for oscillation.
- The net phase shift around the loop 0° (or an integral multiple of 360°). In other word, feedback should be positive.
- The amplifier gain must be greater than the loss in the feedback path.

OSCILLATOR CONDITION

1) $A\beta \geq 1$
2) P/S 0 or 360°

- **Aβ less than 1**
  AβVin is less than Vin the output signal will die out (**Damped Oscillation**).

- **Aβ greater than 1**
  AβVin is greater than Vin the output signal will build up.

- **Aβ equal to 1**
  AβVin is equal to Vin the output signal will steady, ***Undamped Oscillations*** (*Stable oscillator).*

HARTLEY OSCILLATOR

$\boxed{\text{Amp}}$

- The configuration of the transistor amplifier is of a Common emitter amplifier with the output signal 180o out of phase with regards to the input signal
- These two inductances form an autotransformer action and gives the feedback with a phase reversal of 180°, thus the total phase shift becomes 360o to give the feedback positive or regenerative feedback.
- A Hartley oscillator uses an inductive (single tapped-coil) of L1 and L2. Voltage divider to determine the feedback ratio. $\beta = \dfrac{L_2}{L_T}$
- If ignore Mutual inductance, $\beta = \dfrac{L_2}{L_1}$

- When the LC tank is resonant, the circulating current flows through L1 in series with L2. The equivalent L to use in equation is:
- L T = L1 + L2 +2M or L T ≅ L1 + L2
- L1 ,is a primary
- L2 ,is the secondary
- M, Mutual inductance between the coils.
- The tuning capacitor CT allows the Hartley oscillator to be tuned over a wide range of frequency

- The lowest frequency is determined by the maximum capacitance of CT or otherwise.
- The frequency is determined by the tank's **resonant frequency**:

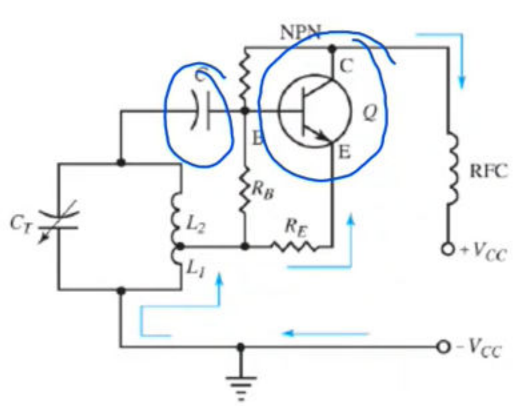
$$f = \frac{1}{2\pi\sqrt{L_T C_T}}$$

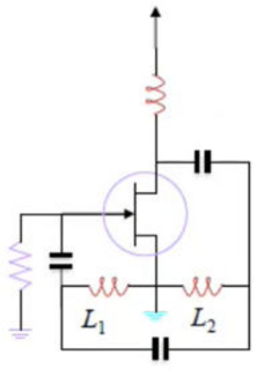
- To start Oscillating, the circuit needs a minimum voltage gain or must be greater than $1/\beta$

$$A_{min} = \frac{L_T}{L_2}$$

- , If ignore Mutual inductance
-

$$A_{min} = \frac{L_1}{L_2}$$

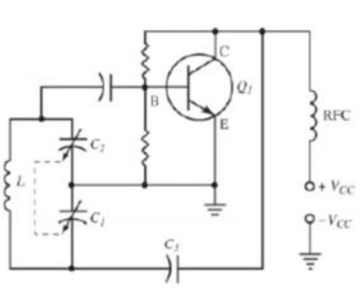


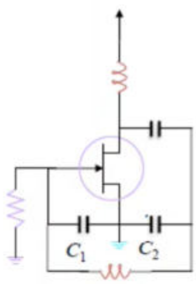


$$f_0 = \frac{1}{2\pi\sqrt{L_{eq}C}} \quad where\ L_{eq} = L_1 + L_2 + 2M$$

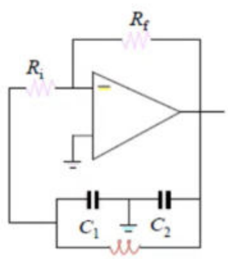
$$M = Mutual\ coupling\ between\ L_1\ \&\ L_2$$

Colpitts Oscillators
BJT; FET; and IC Based





LC network

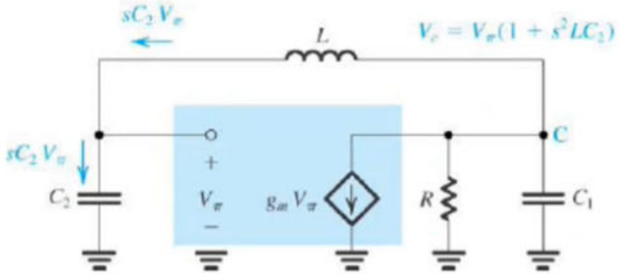


LC network

$$f_0 = \frac{1}{2\pi\sqrt{LC_{eq}}} \quad where\ C_{eq} = \frac{C_1 C_2}{C_1 + C_2}$$

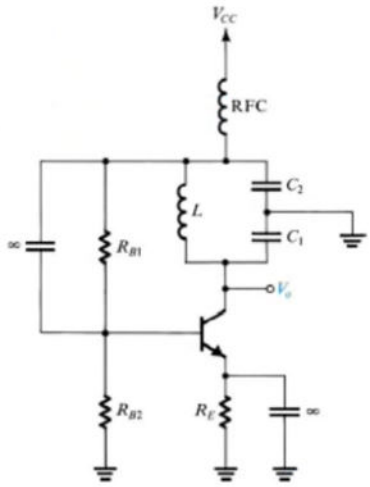
RFC is an impedance which is high (open) at high RF frequencies and low (short) to dc voltages

Equivalent Circuit of the Colpitts Oscillator



$$wo = \frac{1}{\sqrt{L(\frac{C1C2}{C1+C2})}}$$

Complete Circuit for a Colpitts Oscillator



The Phase Shifter Oscillator

R-C phase

The phase-shifter consists of a negative gain amplifier (-K) with a third order RC ladder network in the feedback.

The circuit will oscillate at the frequency for which the phase shift of the RC network is 180º. Only at the frequency will the total phase shift around the loop be 0º or 360º.

The minimum number of RC sections is 3 because it is capable of producing a 180º phase shift at a finite frequency.

$\tan 90 = \infty$

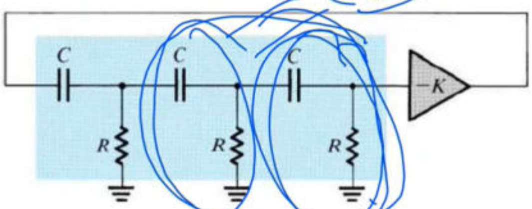
180

RC

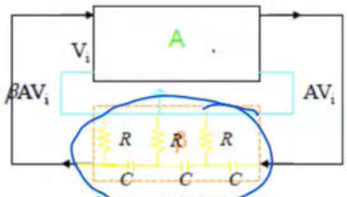
$\angle 180^\circ$

$\tan^{-1} \frac{\omega C}{R}$ ∞ 0

−90 to 90



Phase-shift Oscillator



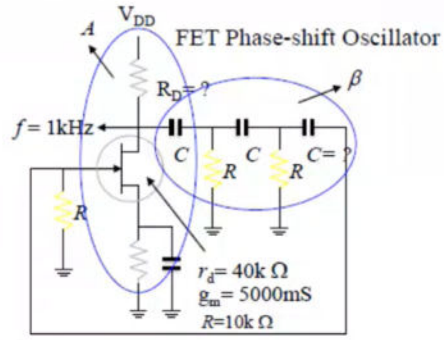
$\beta AV_i = V_i$ (or) $A\beta = 1$

Frequency of oscillation

$$f = \frac{1}{2\pi RC\sqrt{6}} = \frac{1}{2\pi RC\sqrt{2N}}$$

Condition of oscillation

$$\beta \leq \frac{1}{29} \qquad A\beta = 1 \quad \therefore A \geq 29$$



Example:
Determine the value of capacitance C and the value of R_D of the Phase-shift oscillator shown, if the output frequency is 1 kHz. Take r_d = 40k and g_m=5000mS, for the FET and R = 10kW.

$$f = \frac{1}{2\pi RC\sqrt{6}} \Rightarrow C = \frac{1}{2\pi Rf\sqrt{6}} = \frac{1}{2\pi 10k \times 1k\sqrt{6}} = \underline{6.5nF}$$

$$A\beta \geq 1 \; Let \; A = 40 > 29 \; \therefore |A| = g_m R_D = 40 \Rightarrow R_D = \frac{40}{\ldots} = \frac{40}{\ldots} = 8k\Omega$$