unit - 4 AC analysis of BJT circuits & small signal amplifiers.

→ A transistor circuit used as an ac amplifier normally has the signal source capacitor coupled to the circuit i/p terminal.

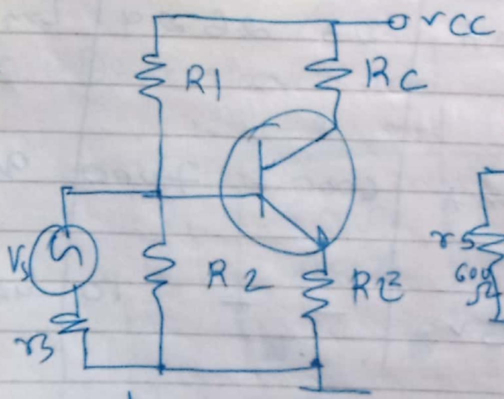
→ A load resister at the output is also usually capacitor - coupled to the circuit.

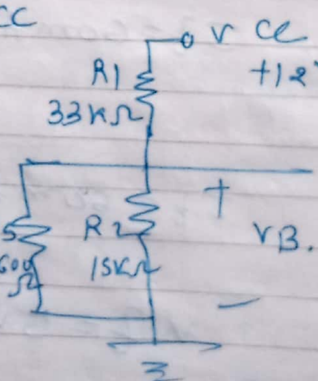
→ Capacitor - Coupling ensures that the source and load do not affect the dc bias conditions in the circuit.

* Coupling and Bypassing Capacitors.

→ To use a transistor circuit to amplify or otherwise process an ac signal, the signal source must be connected to the circuit i/p.

→ if the source is directly connected to the i/p, the circuit bias conditions will be altered.

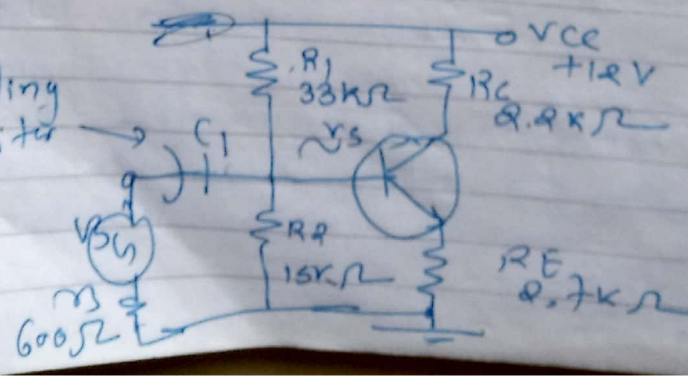




signal source incorrectly direct coupled to the circuit

VB is altered by the dc coupled signal source

Coupling capacitor



signal source capacitor coupled to the circuit.

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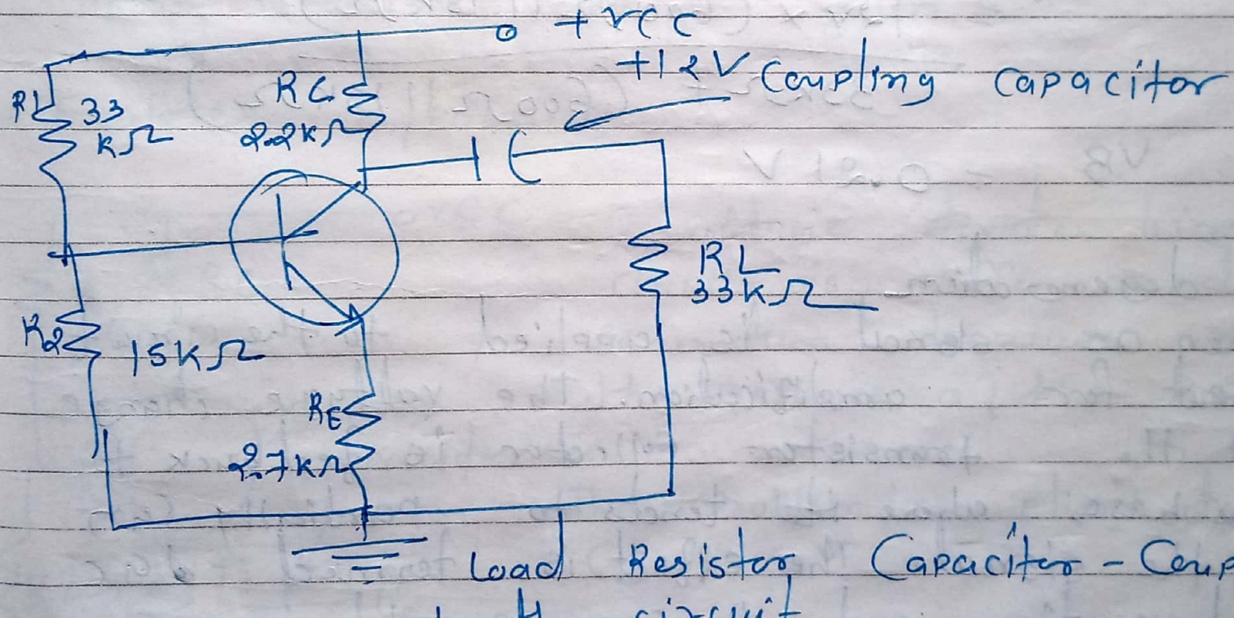
for fig. 2

$$V_B = \frac{V_{CC} \times (r_s \parallel R_2)}{R_1 + (r_s \parallel R_2)}$$ instead of $$V_B = \frac{V_{CC} \times R_2}{R_1 + R_2}$$

→ Capacitor C_1 behaves as a short circuit for the ac signals, so that the signal voltage (v_s) appears at the transistor base. in this case, the signal is said to be ac-coupled to the circuit i/p and C_1 is referred to as a coupling capacitor.

→ A coupling capacitor is usually required at the o/p of a transistor circuit to couple to a load resistor or to another amplification stage.



Load Resistor Capacitor-Coupled to the circuit.

→ The use of an o/p coupling capacitor (C_2) in fig. Like i/p ~~the~~ coupling capacitor, C_2 offers a dc open circuit and behaves as an ac short circuit. Thus, it passes the ac o/p waveform to load w/o affecting the circuit bias conditions.

Ex - Calculate the base bias voltage for the circuit 1.c when no signal source is present and when the signal source is directly connected as in fig 1.a

with no signal source

$$V_B = \frac{V_{CC} \times R_2}{R_1 + R_2} = \frac{12V \times 15k\Omega}{33k\Omega + 15k\Omega}$$

$$= 3.75\,V$$

with the signal source directly connected

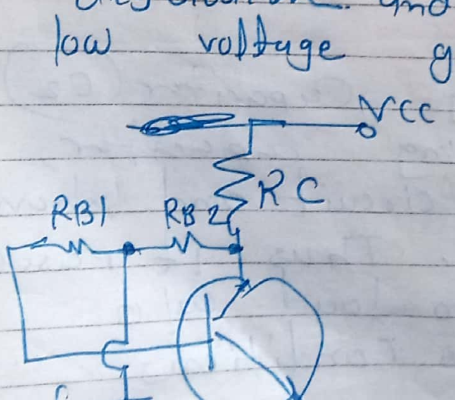
$$V_B = \frac{V_{CC} \times (r_s \| R_2)}{R_1 + (r_s \| R_2)}$$

$$= \frac{12V \times (600\Omega \| 15k\Omega)}{33k\Omega + (600\Omega \| 15k\Omega)}$$

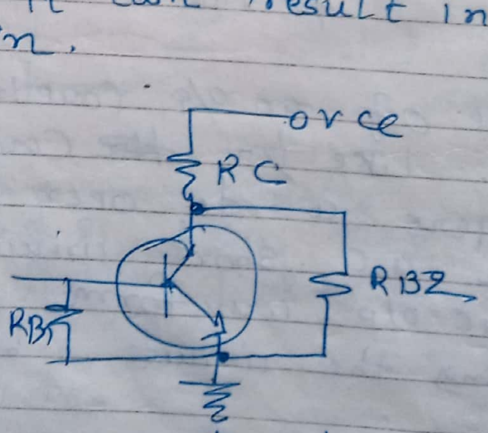
$$V_B = 0.21\,V$$

Ac degeneration

→ when ac signal is applied to the circuit input for amplification, the voltage change at the transistor collector is fed back to the base, where it tends to partially cancel the signal. The effect is termed ac degeration and it can result in a very low voltage gain.



Bypass capacitor used with collector to base bias



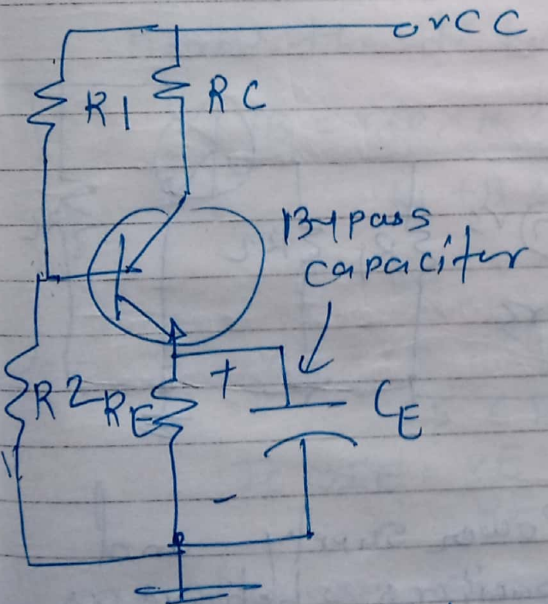
The bypass capacitor in a ac short circuit fig shows how ac degeneration is eliminated in CB bias circuit. R_B is replaced with two approximately equal resistors (R_{B1} and R_{B2}), which add up to R_B. Bypass Capacitor (C_B) is connected from the junction of R_{B1} and R_{B2} to the ground terminal.

→ Capacitor C_B offeres a short circuit to ac signals, so that there is no feedback from the transistor collector to the base.

→ C_B is replaced with a short circuit, R_{B1} and R_{B2} appear in parallel. ~~with the~~

→ large value resistors, so they donot affect the circuit voltage gain.

* Emitter Bypassing



voltage divider bias circuits also suffer ac degeneration because of the presence of the RE.

The problem is eliminated by C_E

* Capacitor polarity

for the proper operation of the circuit, polarities of the capacitors must be connected correctly. The curve bar which indicates -ve terminal must always be connected at d.c. voltage level lower than (or equal to) the d.c. level of +ve terminal (straight ba

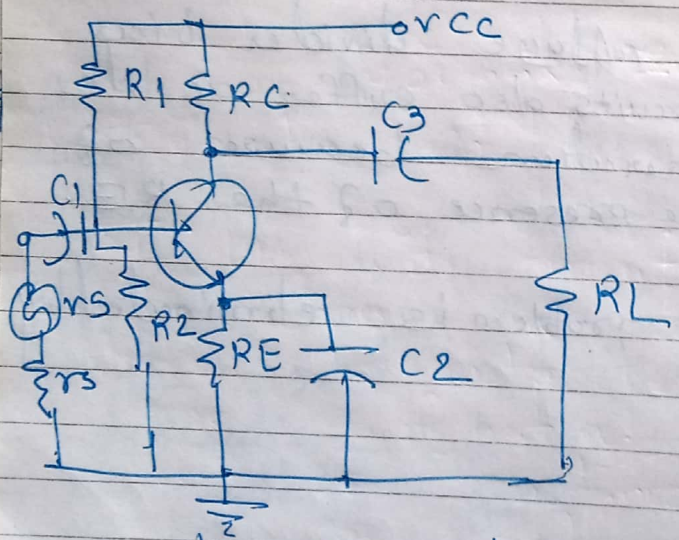
Ac load line

→ Capacitors behave as short circuit to ac signals, so in the ac equivalent circuit for a transistor circuit all capacitors must be replaced with short circuits.

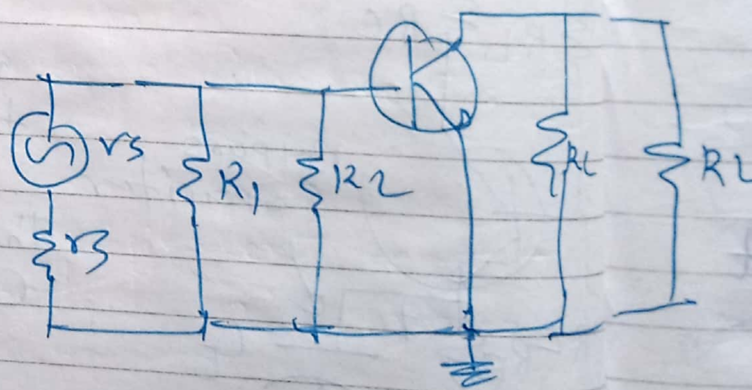
→ All the power supplies have large value capacitors at o/p terminals and these will offer short circuits to ac signals.

→ So short circuits for power supplies and bypass capacitors give Ac equivalent circuit.

→ after that circuit Ac performance can be inverstigated by drawing an ac load line and by substituting transistor model for the device.



Circuit with coupling and bypasss capacitors



Power supply and capacitors behave as ac short circuits.

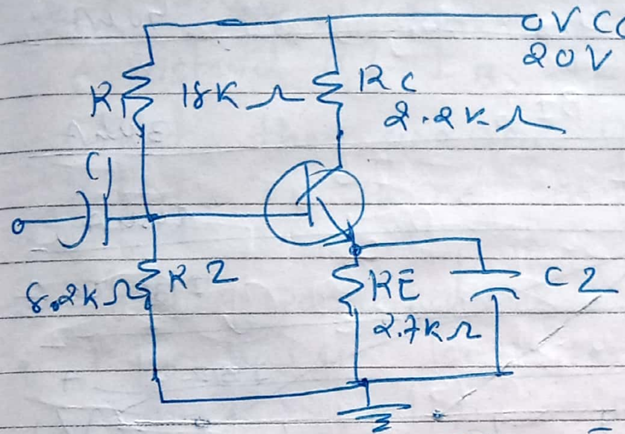
→ the dc load for the circuit (fig 1) is $(R_C + R_E)$.

→ Ac load is $R_C \| R_L$.

* Draw the dc and a.c load lines for the transistor circuit in fig. using the transistor common - emitter charc. show in fig.

→ Drawing the dc load line:

$R_L(dc) = R_C + R_E = 2.2k + 2.7k$
$= 4.9k$



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

when $I_C = 0$

$V_{CE} = V_{CC} = 20V$ (point A)

when $V_{CE} = 0$, $I_C = \frac{V_{CC}}{R_C + R_E} = \frac{20V}{4.9k\Omega}$

$= 4.08\ mA$ (point B)

Draw the dc load line through A and B

$V_B = \frac{V_{CC} \times R_2}{R_1 + R_2} = \frac{20V \times 8.2k\Omega}{18k\Omega + 8.2k\Omega}$

RL

$= 6.3V$

$V_E = V_B - V_{BE} = 6.3V - 0.7V$

$= 5.6V$

$I_C \approx I_E = \frac{V_E}{R_E} = \frac{5.6V}{2.7k\Omega} = 2.07\ mA$

mark the Q point on the dc load line at $I_C = 2.07\ mA$

→ Drawing the ac load line when there is no external RL

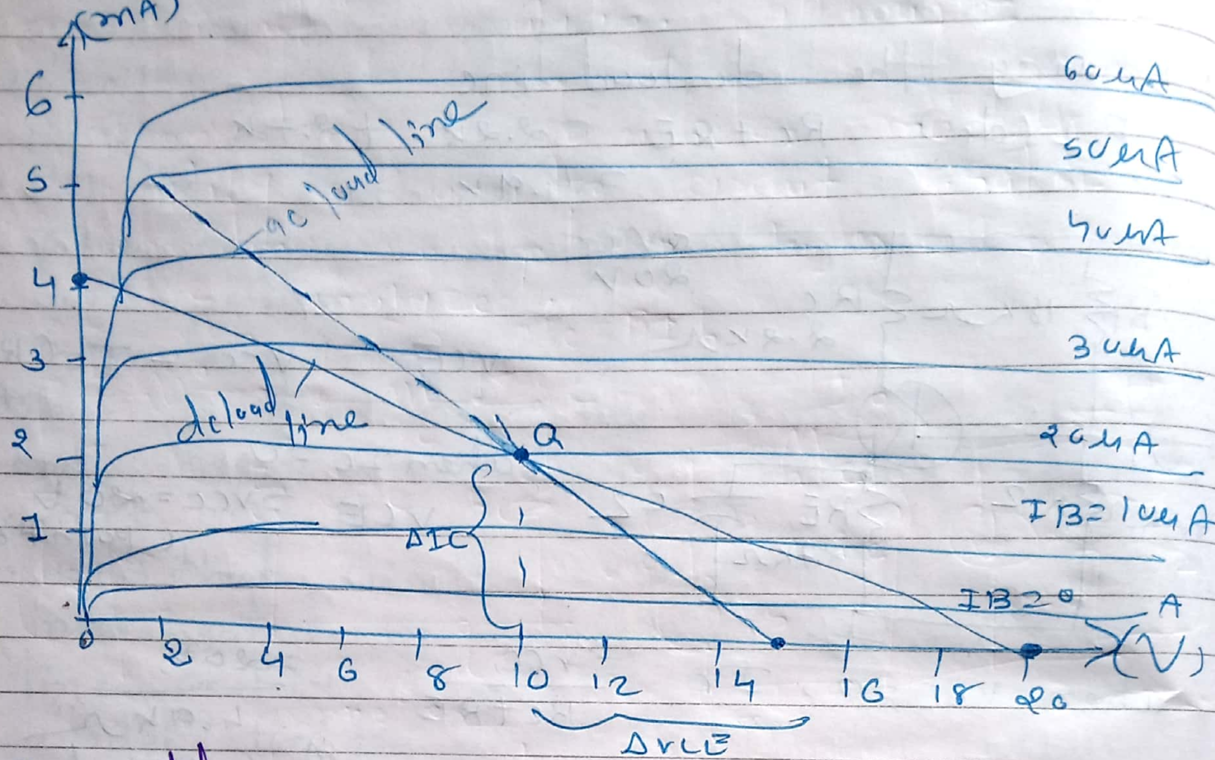
$R_L(ac) = R_C = 2.2k\Omega$

$\Delta I_C = 2.07\ mA$

$\Delta V_{CE} = \Delta I_C \times R_C = 2.07\ mA \times 2.2k\Omega$

Plot point C at $\Delta I_C = 2.07\,mA$ and $\Delta V_{CE} = 4.55V$ from the Q point.

→ Draw the ac load line through points C and Q



O/P voltage swing

$V_{o(max)} \cong 4.5\,V$

* Transistor Models and Parameters

T Equivalent circuit

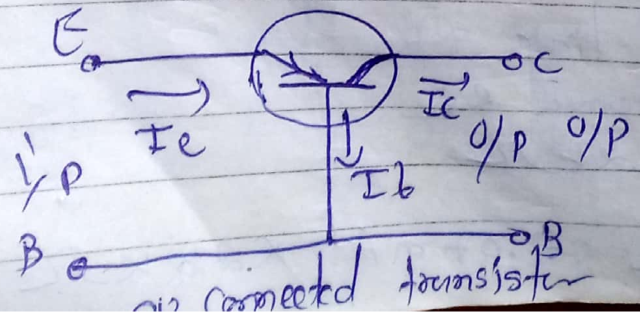
→ fig shows the ac equivalent circuit for a transistor connected in common-base configuration.

r_e - BE resistance

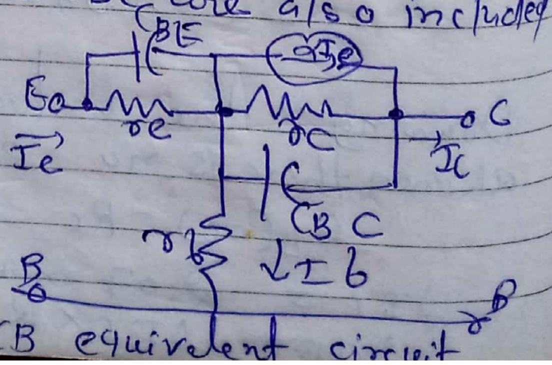
r_c - CB resistance

r_b - base region resistance

Junction capacitance C_{BE} & C_{BC} are also included



ac connected transistor



CB equivalent circuit

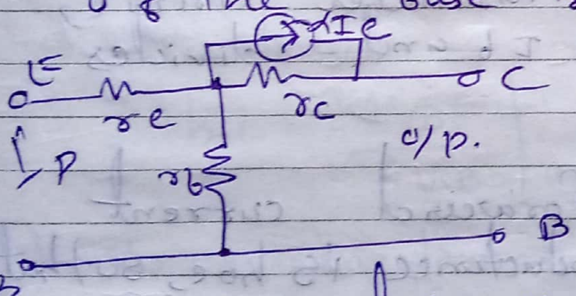
→ current generator is included in parallel with r_c and C_{BC}.

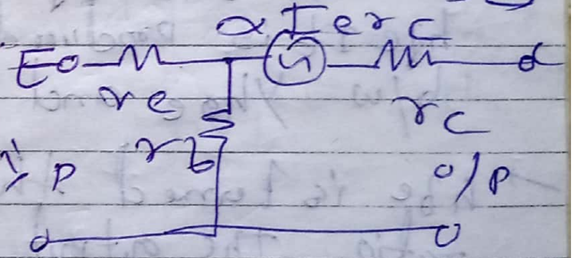
$$\alpha = I_c / I_e$$

→ complete circuit is known as the T-equivalent circuit, or the r-parameter equivalent circuit.

→ currents in fig are designated I_b, I_c and I_e (instead of I_B, I_C and I_E) to indicate that they are ac quantities rather than dc. r_c, r_b, r_e and α are also ac quantities

→ r - parameters
- r_e has a low resistance value ~~because~~ (typically 25 Ω)
- r_c has a high resistance value (typically 100 kΩ to 1 MΩ)
- r_b depends upon the doping density of the base material. (100Ω to 200Ω)



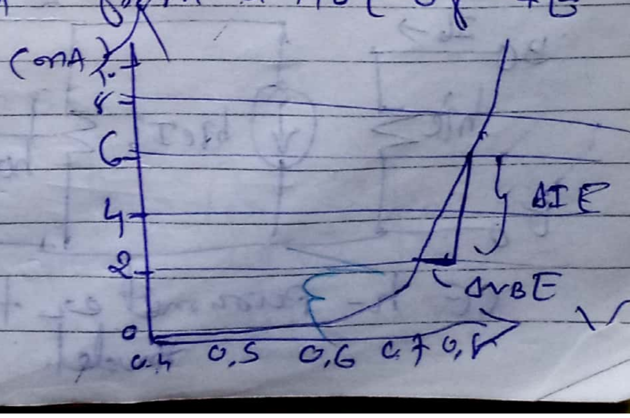


using current source

Determination of r_e

→ it can be determined from a plot of I_E versus V_{BE}

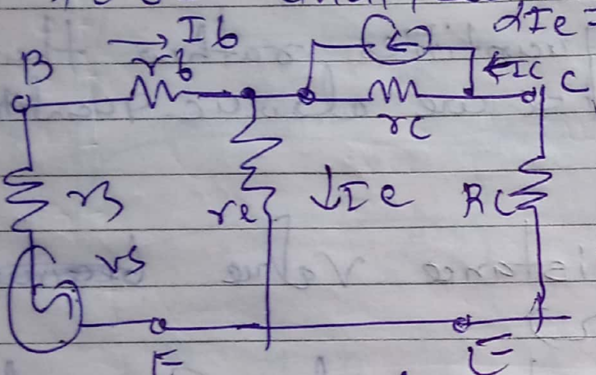
$$r_e = \frac{\Delta V_{BE}}{\Delta I_E}$$

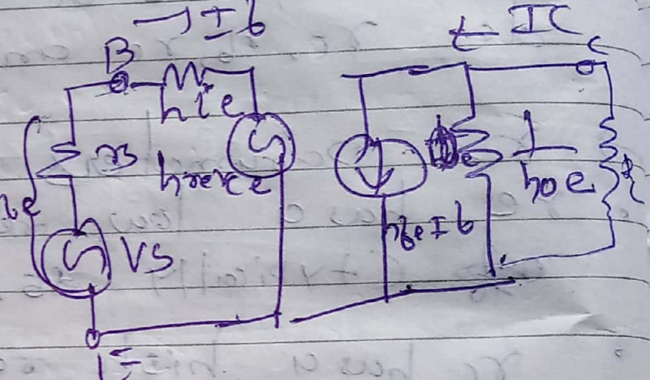


h- parameters

→ The hybrid parameters (or h parameters) are much more convenient for circuit analysis. These are used only for ac circuit analysis, ~~although dc case~~

→ Transistor h- parameter models simplify transistor circuit analysis by seperating i/p and o/p stages of a circuit to be analyzed.





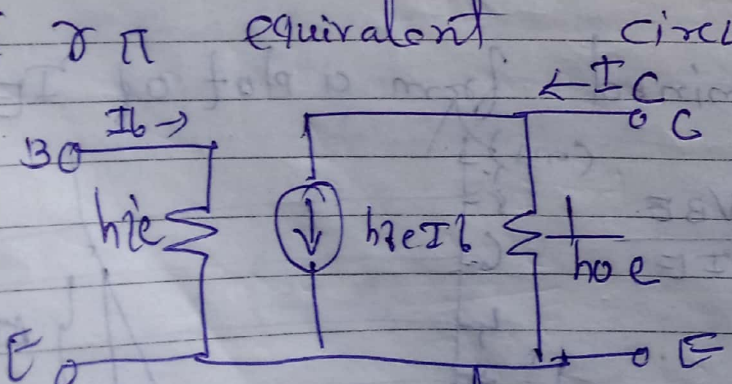
CE r-parameter equivalent circuit

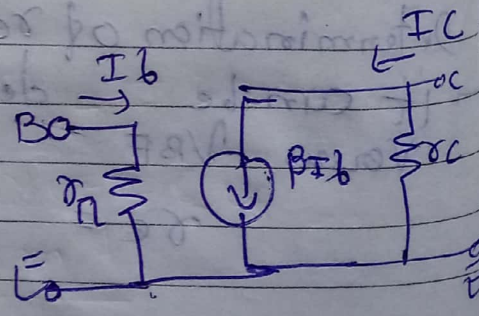
→ hre is reverse voltage transfer ratio

→ at o/p side of h- parameter circuit, hfe Ib is produced by Ib and divides b/w 1/hoe and Rc.

→ hfe is termed the forward current ratio. The output conductance is hoe, so that 1/hoe is a resistance.

* rπ equivalent circuit





CE rπ transistor model

CE h- parameter transistor model.

in fig.1 feedback generator ($h_{re} v_{ce}$) is omitted. The effect of $h_{re} v_{ce}$ is very small so it can be neglected.

→ This approximate h-parameter circuit is reproduced in fig 2 with the components labelled as r-parameters $r_\pi = h_{ie}$, $\beta I_b = h_{fe} I_b$, $r_c = 1/h_{oe}$. This circuit is known as a hybrid π model, is sometimes used instead of the h-parameter circuit.

→ Defination of h-parameters

are hie (i - input, e - common emitter)

1) Ac i/p resistance h_{ie} defined as the ac i/p voltage divided by the ac i/p current.

$$h_{ie} = \frac{V_{be}}{I_b}$$

$$h_{ie} = \left.\frac{V_{be}}{I_b}\right|_{V_{CE}}$$

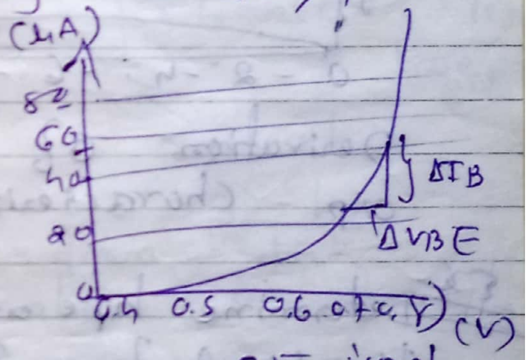


fig 1 CE i/p ch.

at dc level

$$h_{ie} = \left.\frac{\Delta V_{BE}}{\Delta I_B}\right|_{V_{CE}}$$

2) The reverse transfer ratio

$$h_{re} = \left.\frac{\Delta V_{be}}{\Delta V_{ce}}\right|_{I_b}$$

for dc

$$h_{re} = \left.\frac{\Delta V_{BE}}{\Delta V_{CE}}\right|_{I_B}$$

3) The forward current transfer ratio h_{fe}

$$h_{fe} = \left.\frac{I_C}{I_b}\right|_{V_{CE}} \text{ or } \left.\frac{\Delta I_C}{\Delta I_B}\right|_{V_{CE}}$$

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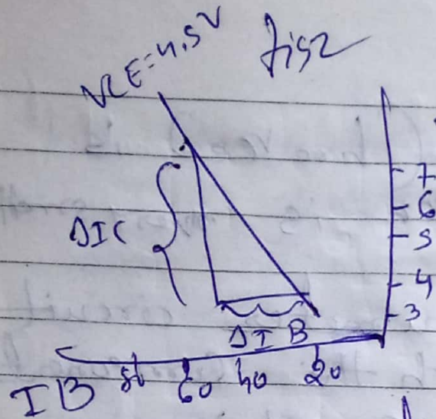
fig2



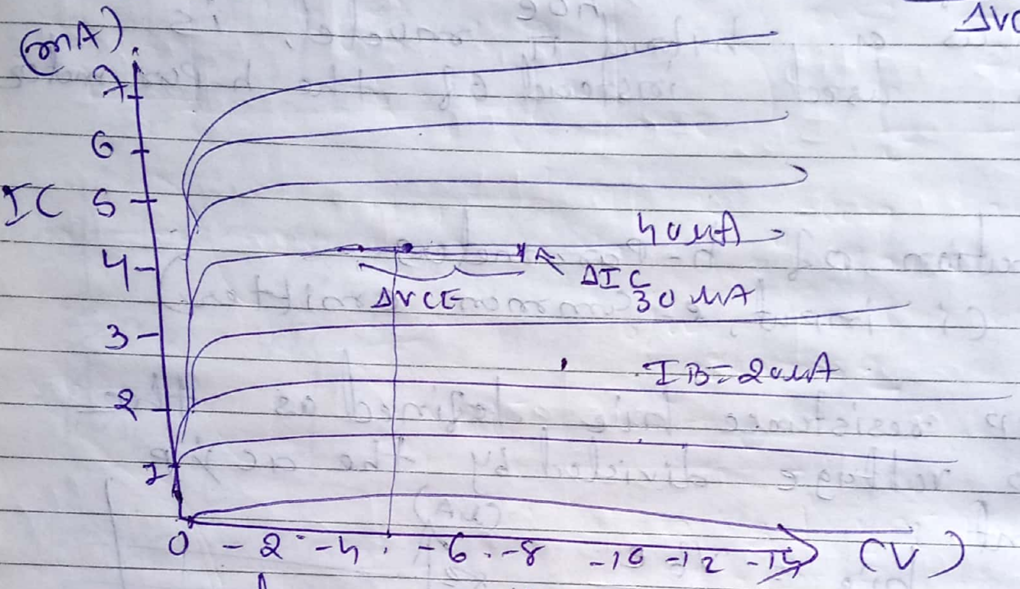
CE current gain Char.

4) out put Condunctance
hoe

$$hoe = \frac{Ic}{Vce}\Big|_{IB}$$

or

$$hoe = \frac{\Delta Ic}{\Delta VCE}\Big|_{IB}$$



Derivation of hoe from the CE o/p characteristics.

Ex Determine hfe and hoe for VCE = 4.5V and IB = 40uA from fig 2 and 3

$VCE = 4.5V, \quad IB = 40uA$

$\Delta IC = 4mA, \quad \Delta IB = 30uA$

$$hfe = \frac{\Delta IC}{\Delta IB} = \frac{4mA}{30uA} = 133$$

from o/p ch. fig. 3 VCE = 4.5V, IB = 40uA

$\Delta IC = 0.2mA, \quad \Delta VCE = 6V$

$$hoe = \frac{\Delta IC}{\Delta VCE} = \frac{0.2mA}{6V}$$

$= 33.3\,us$

$$1/hoe = \frac{1}{33.3us} = 30k\Omega$$

* Parameter relationships
In datasheets only CE h-parameters are stated. However CB and CC h-parameters can be determined from the CE-h parameters. r parameters can also be calculated from the CE h parameters.

CE to CB h-parameters	CE to CC h parameters	CE-h parameters to r-parameters
$h_{ib} \approx \frac{h_{ie}}{1+h_{ie}}$	$h_{ic} = h_{ie}$	$\alpha \approx \frac{h_{fe}}{1+h_{fe}}$
$h_{rb} \approx \frac{h_{ie}h_{oe}}{1+h_{fe}} - h_{re}$	$h_{rc} = 1 - h_{re}$	$r_c = \frac{1+h_{fe}}{h_{oe}}$
$h_{fb} \approx \frac{h_{fe}}{1+h_{fe}}$	$h_{fc} = 1 + h_{fe}$	$r_e = \frac{h_{ie}}{1+h_{fe}} \approx r_e'$
$h_{ob} \approx \frac{h_{oe}}{1+h_{fe}}$	$h_{oc} = h_{oe}$	$r_b = h_{ie} - \frac{h_{re}(1+h_{fe})}{h_{oe}}$
		$r_\pi = h_{ie}$
		$\beta = h_{fe}$

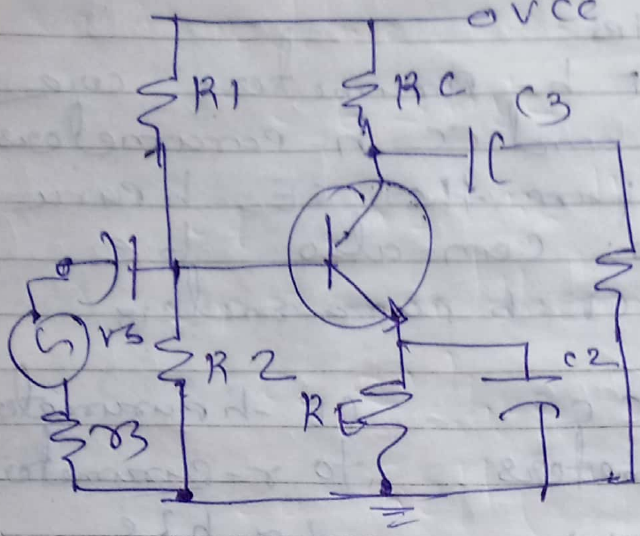
Ex calculate h_{fc}, h_{ob} and α from the parameters determined in above example.

$h_{fc} = 1 + h_{fe} = 1 + 133$
$= 134$

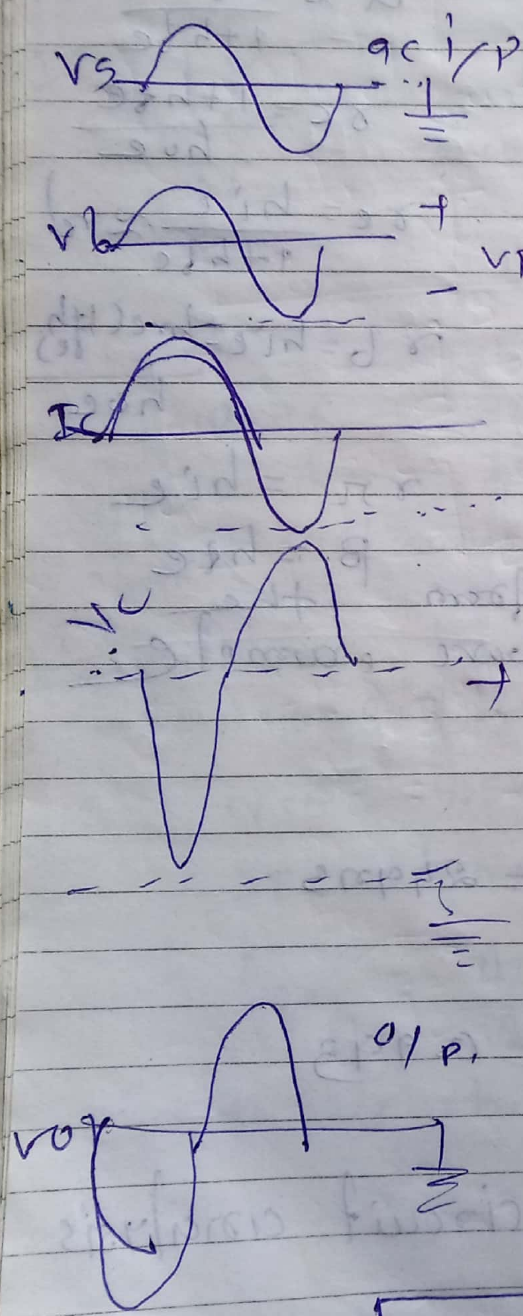
$h_{ob} \approx \frac{h_{oe}}{1+h_{fe}} \approx \frac{33.3\,\mu S}{1+133} = 249\,nS$

$\alpha \approx \frac{h_{fe}}{1+h_{fe}} \approx \frac{133}{1+133} = 0.993$

Common-Emitter circuit analysis



current and voltage waveforms for the CE circuit are illustrated in fig.



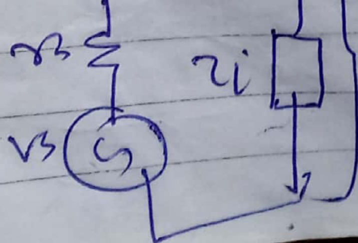
it is seen that there is a 180° phase shift b/w the i/p and o/p waveforms.

→ when $V_S \uparrow$ $V_{BE} \uparrow$ $I_C \uparrow$ there by increasing the voltage drop across RC, Thus $V_C \downarrow$. VC capacitor coupled to o/p ro

→ so as Vs increases in +ve direction, Vo goes in -ve direction, same viceversa.

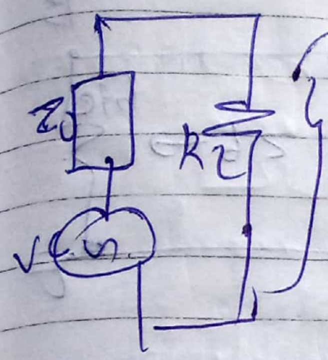
→ The circuit has i/p impedance Z_i and o/p impedance (Z_o)

→ voltage gain depends on the transistor parameters and on resistors RC and RL



$$V_i = \frac{V_S \times Z_i}{r_s + Z_i}$$

Division of signal voltage

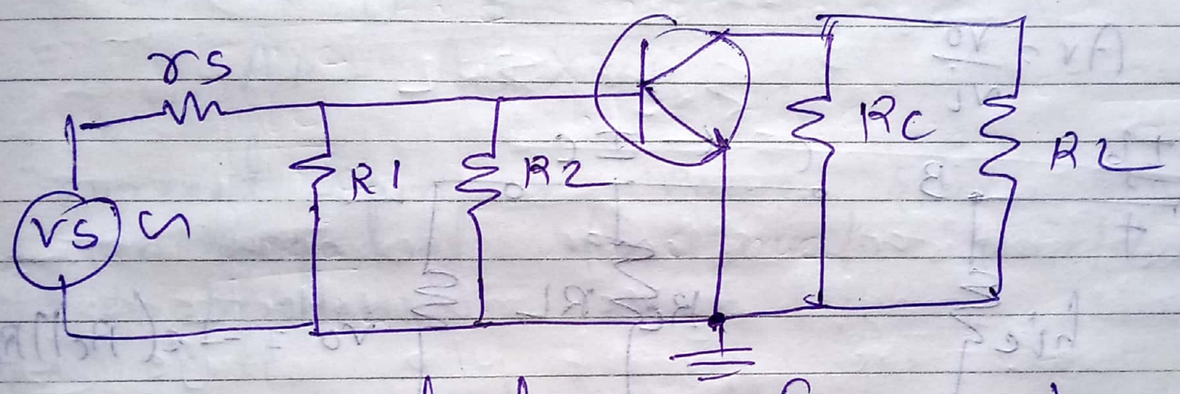


$$v_o = \frac{v_i \times R_L}{Z_o + R_L}$$

voltage Division of o/p voltage

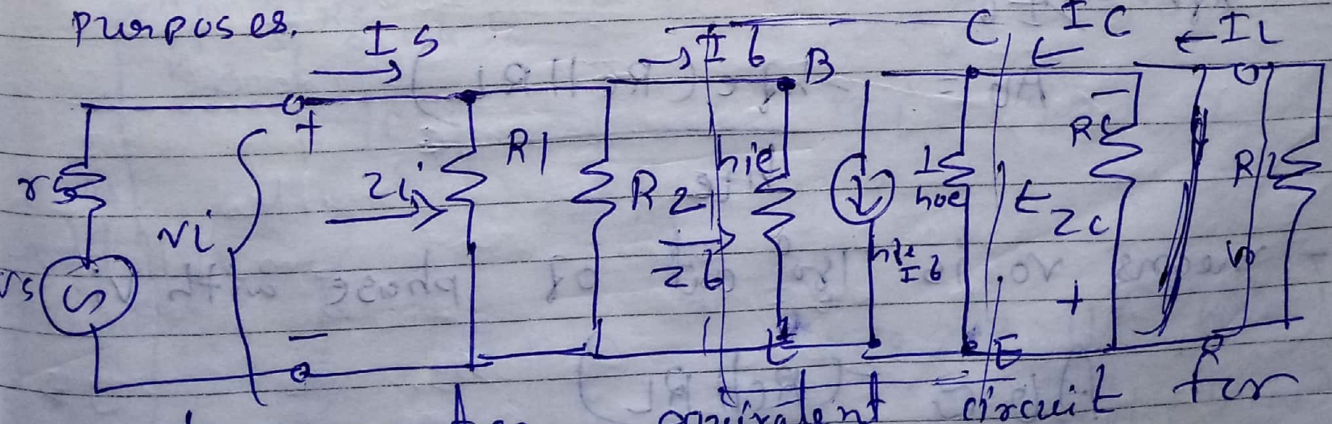
h- parameter equivalent circuit

→ The first step in ac analysis of a Transistor circuit is to draw the ac equivalent circuit, by placing short circuits in place of power supply and Capacitors.



ac equivalent cir. for CE trans. circ.

→ Now replace transistor in ac. equivalent circuit with its h-parameter model. This gives CE-h parameter equivalent circuit. Note that $h_{re} v_c$ is omitted because its effect is unimportant for most practical purposes.

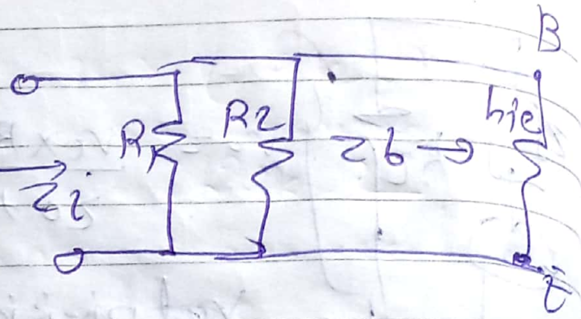


h-parameter equivalent circuit for CE circuit.

1) I/P impedance

$Z_b \simeq h_{ie}$

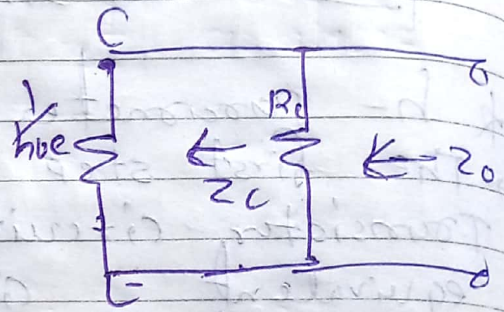
$Z_i = R_1 \| R_2 \| Z_b$



2) O/P impedance

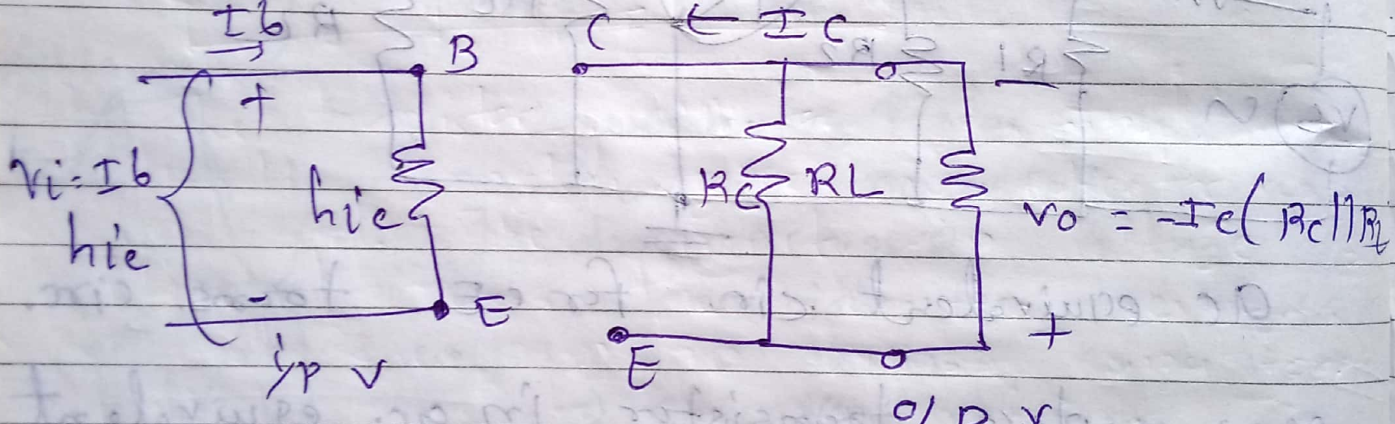
$Z_c \simeq 1/h_{oe}$

$Z_o = R_C \| (1/h_{oe})$



3) voltage gain

$A_v = \frac{v_o}{v_i}$



$v_i = I_b h_{ie}$, $v_o = -I_c(R_C \| R_L)$

$$A_v = \frac{-I_c(R_C \| R_L)}{I_b h_{ie}}$$

$h_{fe} = I_c / I_b$

$$A_v = \frac{-h_{fe}(R_C \| R_L)}{h_{ie}}$$

- means v_o is 180^0 out of phase with v_i

$$A_v \simeq \frac{-(R_C \| R_L)}{h_{ib}}$$

* current gain

$h_{fe} = \frac{I_c}{I_b}$ (Transistor ac current gain)

I_s divided b/w hie and bias resistors
I_c divided b/w R_C and R_L.

overall circuit current gain

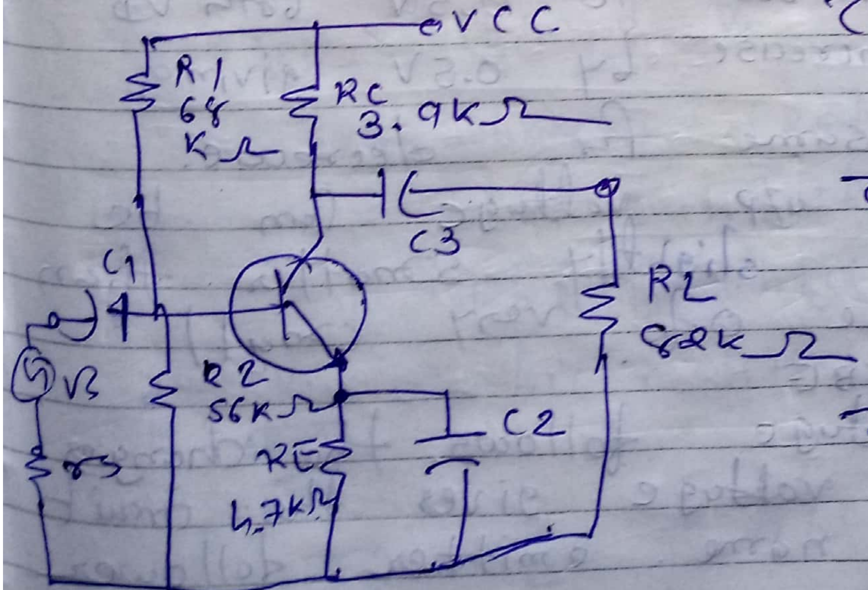
$$A_i = \frac{h_{fe} R_C R_B}{(R_C + R_L)(R_C + h_{ie})}$$

* power gain

$$A_p = A_v \times V_i$$

current gain & power gain largely unimportant for most practical applications.

ex
The transistor in the CE circuit in fig has the following parameters; h_{ie} = 2.1kΩ, h_{fe} = 75, h_{oe} = 1µs. Calculate the circuit i/p impedance, o/p impedance, and voltage gain.



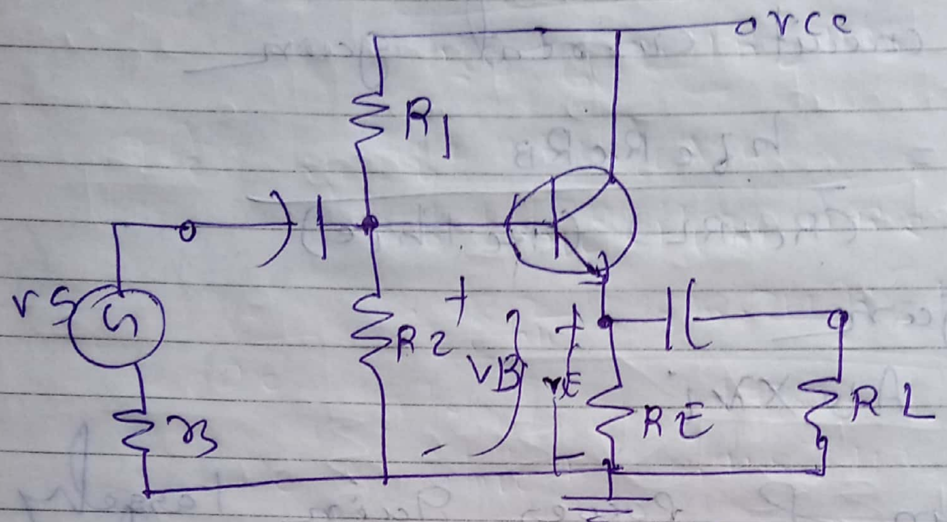
$Z_i = R_1 \| R_2 \| h_{ie}$
$= 68k\Omega \| 56k\Omega \| 2.1 k\Omega$
$Z_i = 1.97 K\Omega$

$Z_o = R_C \| (1/h_{oe})$
$= [3.9k\Omega \| (1/1\mu s)]$
$\simeq 3.9k\Omega$

$$A_v = \frac{-h_{fe}(R_C \| R_L)}{h_{ie}} = \frac{-75 \times (3.9k\Omega \| 82k\Omega)}{2.1k\Omega}$$

$$= -133$$

Common - collector circuit analysis



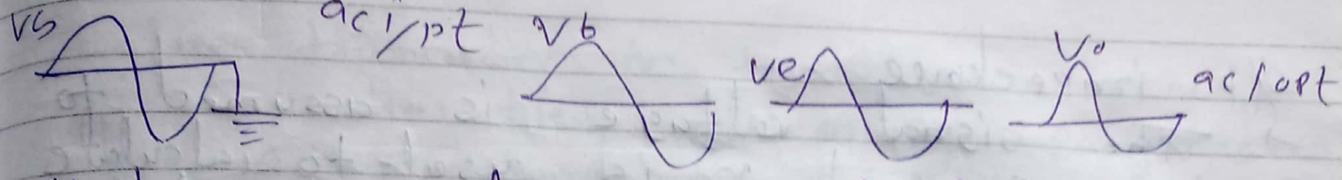
→ The transister collector terminal is directly connected to VCC. no collector resistor is used. The circuit o/p voltage is develped across the emitter resistor (RE) and there is no bypass capacitor.

→ VS↑ VB↑ VE↑ ($V_E = V_B - V_{BE}$) Vo↑ $\hat{V_{BE}}$ is constant

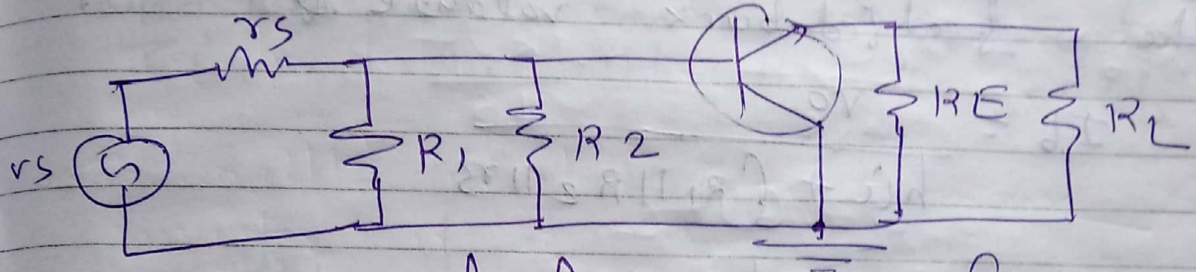
→ when VS increases to 0.5V, both VB and VE increase by 0.5V, giving Vo = 0.5V same for decrease.

→ Actually the o/p voltage can be shown to be slightly smaller than th i/p because of very small change in VBE

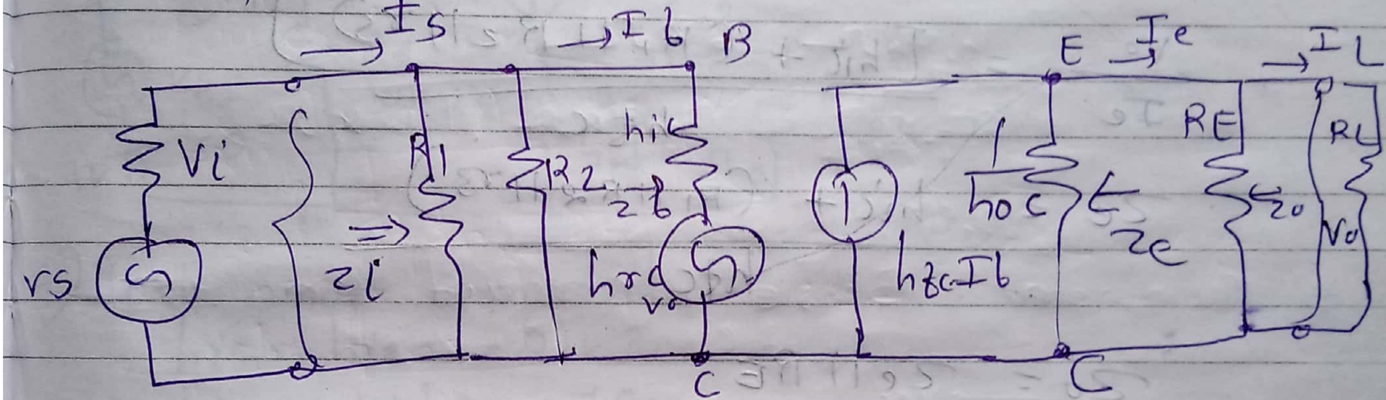
→ CC o/p voltage follows the changes in signal voltage gives the circuit its other name: emitter follower



h-parameter equivalent circuit.



AC equivalent circuit for CC transistor circuit



all of vo is feedback to the i/p. so, unlike the case of CE circuit, the feedback generator cannot be omitted in the equivalent circuit of CC amplifier

1) i/p impedance

$V_i = I_b h_{ic} + h_{rc} V_o \qquad (h_{rc} = 1)$

$= I_b h_{ic} + I_e (R_E \| R_L)$

$= I_b h_{ic} + h_{fc} I_b (R_E \| R_L)$

$V_i = I_b [h_{ic} + h_{fc} (R_E \| R_L)]$

$\frac{V_i}{I_b} = h_{ic} + h_{fc} (R_E \| R_L)$

or $Z_b = h_{ic} + h_{fc} (R_E \| R_L)$

$Z_i = R_1 \| R_2 \| Z_b$

o/p impedance

→ The signal voltage is assumed to be zero, and vo is used to calculate Ie. with rs = 0, Ib is produced by the ~~feed~~ fed-back voltage.

$$I_b = \frac{v_o}{h_{ic} + (R_1 \| R_2 \| r_s)}$$

$$I_e = h_{fc} I_b = \frac{h_{fc} v_o}{h_{ic} + (R_1 \| R_2 \| r_s)}$$

$$\frac{v_o}{I_e} = \frac{[h_{ic} + (R_1 \| R_2 \| r_s)]}{h_{fc}}$$

$$Z_e = \frac{h_{ic} + (R_1 \| R_2 \| r_s)}{h_{fc}}$$

$$Z_o = Z_e \| R_E$$

Voltage gain

o/p voltage from CC circuit is almost exactly equal to the i/p voltage.

$$V_i = I_b [h_{ic} + h_{fc}(R_E \| R_L)]$$

$$V_o = I_e (R_E \| R_L)$$

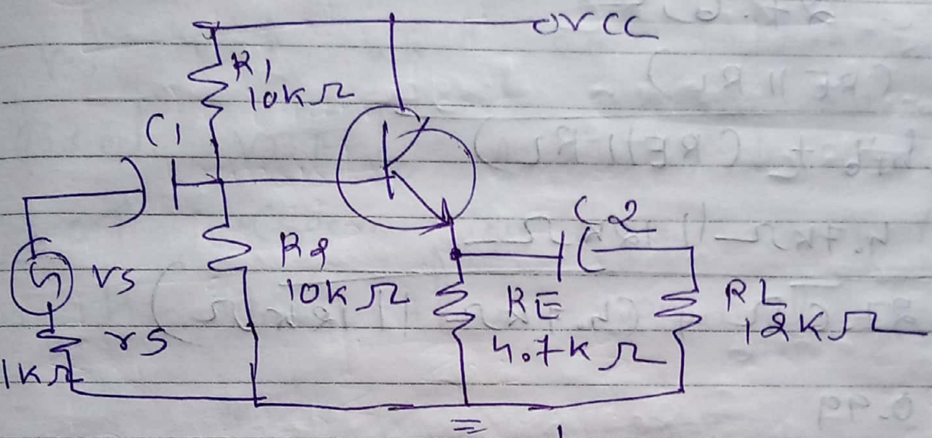
$$A_v = \frac{v_o}{v_i} = \frac{I_e (R_E \| R_L)}{I_b [h_{ic} + h_{fc}(R_E \| R_L)]}$$

$$A_v = \frac{(R_E \| R_L)}{h_{ib} + (R_E \| R_L)}$$

$R_E \| R_L$ is so much larger than h_{ib} so

$$A_v \approx 1$$

Ex The transistor in the CC circuit in fig has the following parameters $h_{ie} = 2.1\,k\Omega$ and $h_{fe} = 75$. (a) calculate the circuit i/p and o/p impedance with RL not connected. (b) calculate Zi and Av with RL connected.



a) R_L is not connected

$h_{ic} = h_{ie} = 2.1\,k\Omega$

$h_{fc} = 1 + h_{fe} = 76$

$Z_b = h_{ic} + h_{fc}(R_E \| R_L) = 2.1\,k\Omega + 76(4.7\,k\Omega)$

$= 359.3\,k\Omega$

$Z_i = R_1 \| R_2 \| Z_b = 10\,k\Omega \| 10\,k\Omega \| 359.3\,k\Omega$

$= 4.93\,k\Omega$

$$Z_e = \frac{h_{ic} + (R_1 \| R_2 \| r_s)}{h_{fc}} = \frac{2.1\,k\Omega + (10\,k\Omega \| 10\,k\Omega \| 1\,k\Omega)}{76}$$

$Z_e = 38.6\,\Omega$

$Z_o = Z_e \| R_E = 38.6\,\Omega \| 4.7\,k\Omega$

$= 38.3\,\Omega$

b) R_L connected

$Z_b = h_{ic} + h_{fc}(R_E \| R_L)$

$= 2.1\,k\Omega + 76\,(4.7\,k\Omega \| 12\,k\Omega)$

$Z_b = 258.8k\Omega$

$Z_i = R_1 \| R_2 \| Z_b$

$= 10k\Omega \| 10k\Omega \| 258.8k\Omega$

$= 4.91k\Omega$

$$h_{ib} = \frac{h_{ie}}{1+h_{fe}} = \frac{2.1k\Omega}{1+75}$$

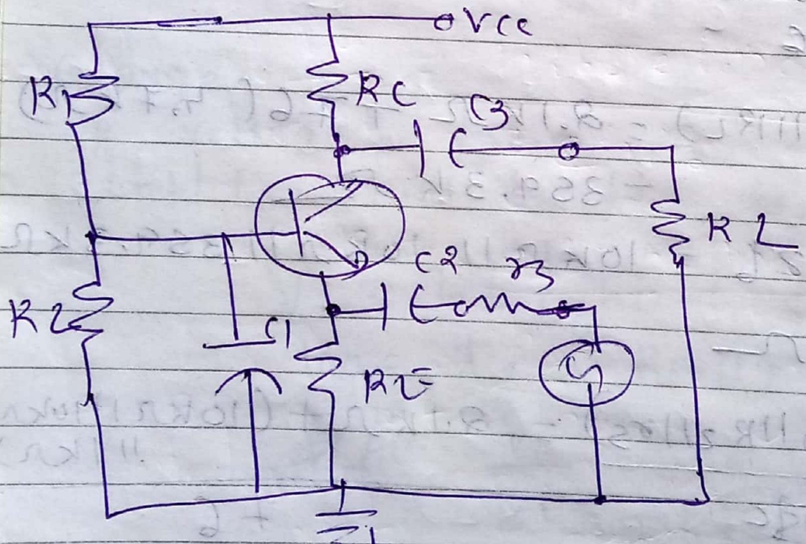
$= 27.6\Omega$

$$A_v = \frac{(R_E \| R_L)}{h_{ib} + (R_E \| R_L)}$$

$$= \frac{4.7k\Omega \| 12k\Omega}{27.6\Omega + (4.7k\Omega \| 12k\Omega)}$$

$= 0.99$

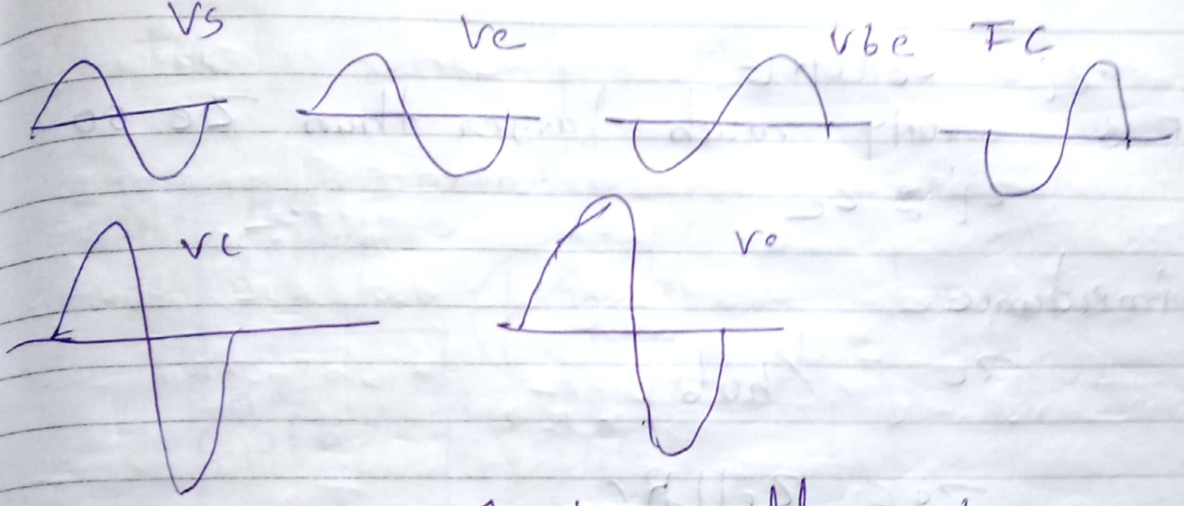
* Common Base circuit analysis



→ i/p signal is applied to the transistor emitter terminal (via C2) instead of base

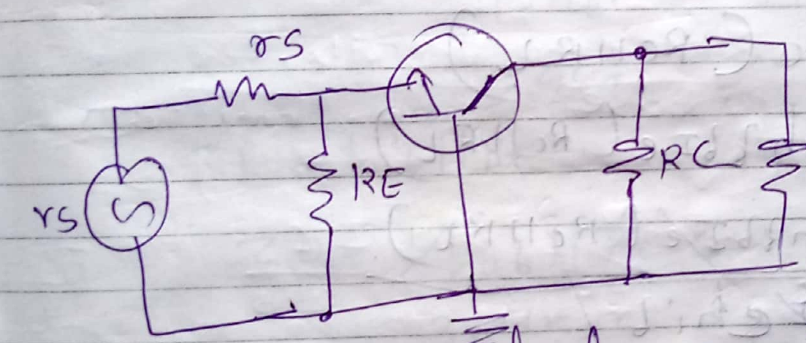
→ there is no bypass capacitor across the RE, but the base terminal is ac grounded via capacitor C1.

→ o/p voltage developed across the RC.

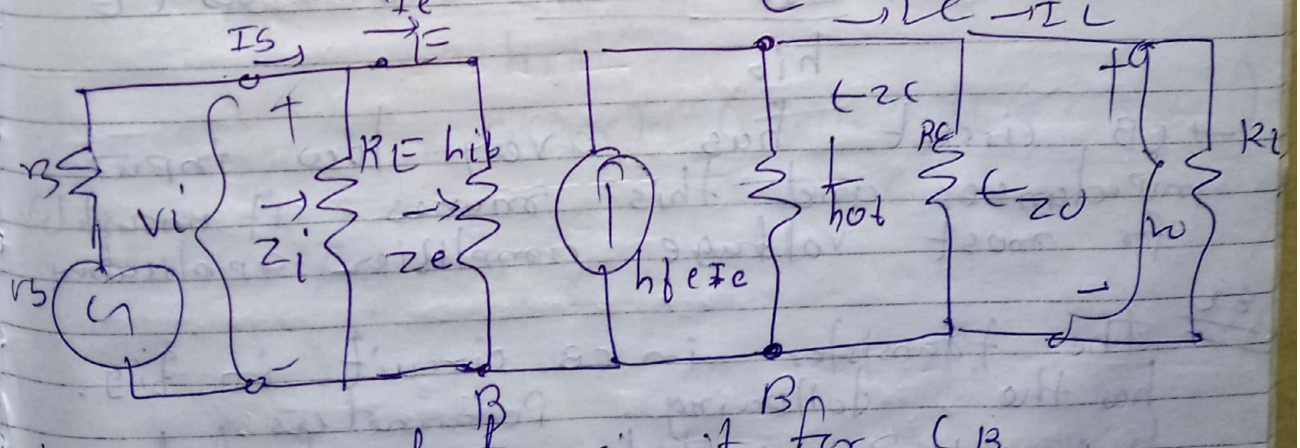


~~vs~~ VS↑ VE↑, base voltage ~~vbe~~ remain fixed. VBE↓ ↓IC, ↓VRC, VC↑ VO↑ as seen in the curve form

→ h- parameter equivalent circuit.



ac equivalent circuit for CB



h parameter AC equivalent circuit for CB

1) Input impedance

$z_e = h_{ib}$

hib is around 21Ω for low current transistor.

$Z_i = Z_e || R_E$

R_E is usually much larger than Z_e so

$Z_i \approx Z_e$

2) o/p impedance

$$Z_c = 1/h_{ob}$$

$$Z_o = Z_c || R_C$$

Z_c is normally much larger than R_C, $Z_o \approx R_C$

3) voltage gain

$$V_i = I_e h_{ib}$$

$$V_o = I_c (R_C || R_L)$$

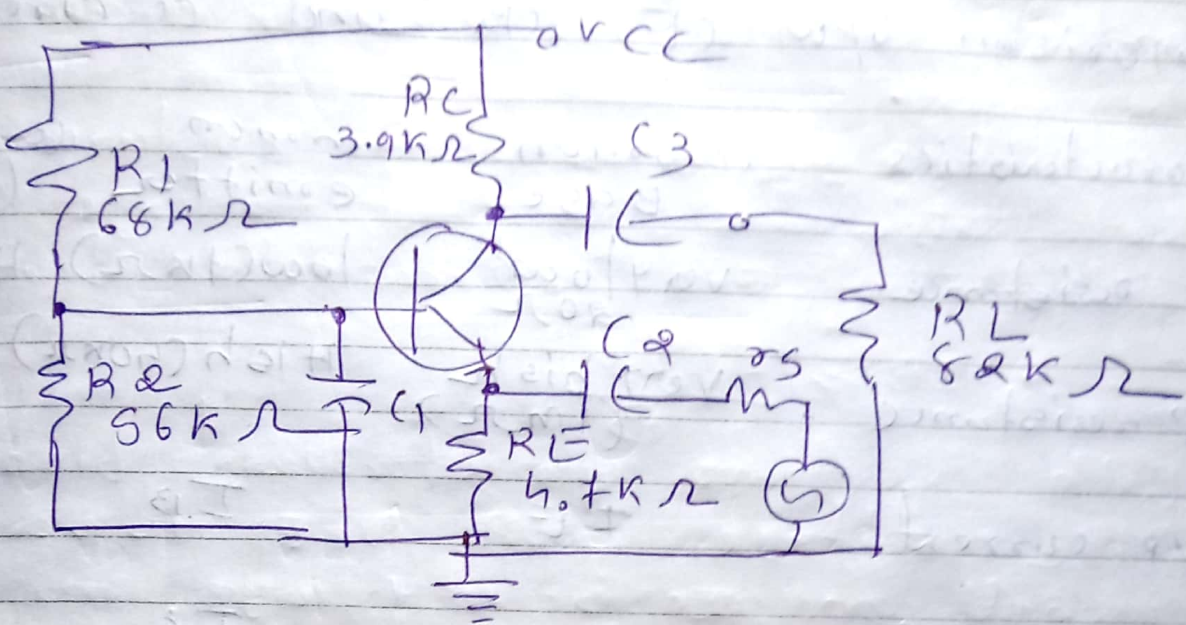
$$= h_{fb} I_e (R_c || R_L)$$

$$\frac{V_o}{V_i} = \frac{h_{fb} \cancel{I_e} (R_c || R_L)}{\cancel{I_e} h_{ib}}$$

$$A_v = \frac{h_{fb} (R_c || R_L)}{h_{ib}}$$ (Same as CE

→ CB circuit has a very low input impedance, and this makes it unsuitable for most voltage amplifier applications

Ex The transistor in CB circuit in fig. has the following parameters: $h_{ie} = 2.1 k\Omega$ and $h_{fe} = 75$. Calculate the circuit i/p and o/p impedances and voltage gain.



$$h_{ib} = \frac{h_{ie}}{1+h_{fe}} = \frac{2.1k\Omega}{1+75} = 27.6\Omega$$

$$h_{fb} = \frac{h_{fe}}{1+h_{fe}} = \frac{75}{1+75}$$

$$= 0.987$$

$$z_i = h_{ib} \| R_E = 27.4\Omega$$

$$z_o = 1/h_{ob} \| R_C \approx R_C$$

$$= 3.9k\Omega$$

$$A_v = \frac{h_{fb}(R_C \| R_L)}{h_{ib}}$$

$$= 0.987 \frac{(3.9k\Omega \| 82k\Omega)}{27.6\Omega}$$

$$A_v = 133$$

* Comparison b/w CE, CB and CC circuits

characteristics	Common Base	Common emitter	Common Collector
i/p resistance	very low 20Ω	low (1kΩ)	High (50
o/p resistance	very high (1MΩ)	High (40kΩ)	Low
i/p current	I_E	I_B	I_B
o/p current	I_C	I_C	I_E
i/p voltage applied b/w	Emitter and Base	Base and Emitter	Base collect
o/p voltage taken b/w	collector and Base	collector and emitter	emit coll e
current amplification factor	$\alpha = \frac{I_C}{I_E}$	$\beta = \frac{I_C}{I_B}$	$\gamma = \frac{I_E}{I_B}$
current gain	less than unity	High (2 to few hundreds)	High (few
voltage gain	Medium	Medium	
Applications	As a i/p stage of multi stage amplifier	for audio signal amplification	

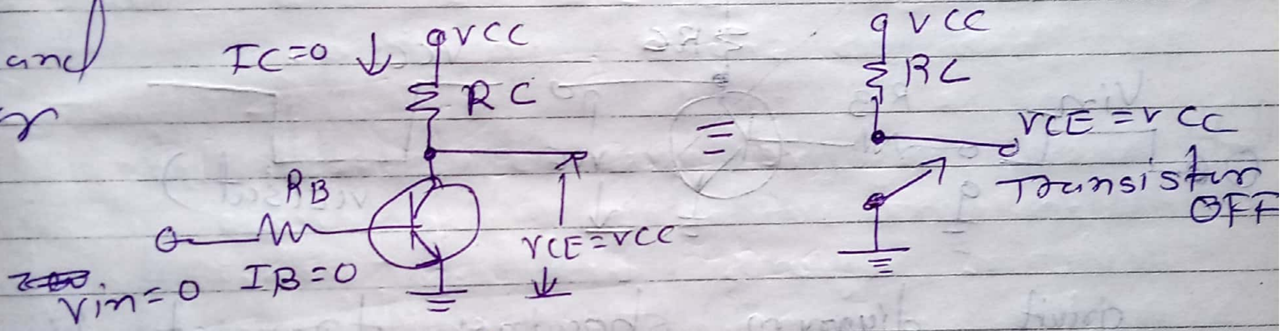
* Transistor as a switch
→ Transistor can be used for two types of applications like amplification & switching
→ for amplification, transistor is biased in its active region
→ for switching, it is biased to operate

in saturation (fully on) or cutoff (fully off) regions

1. Transistor in cutoff region (Transistor as an open switch)

→ In cutoff region both the junctions of a transistor are reverse biased and a very small reverse current flows through the transistor

→ voltage drop across the transistor & V_{CE} is high.
$V_{in} = 0$, $I_B = 0$ and $I_C = 0$



→ Apply KVL to collector circuit of fig

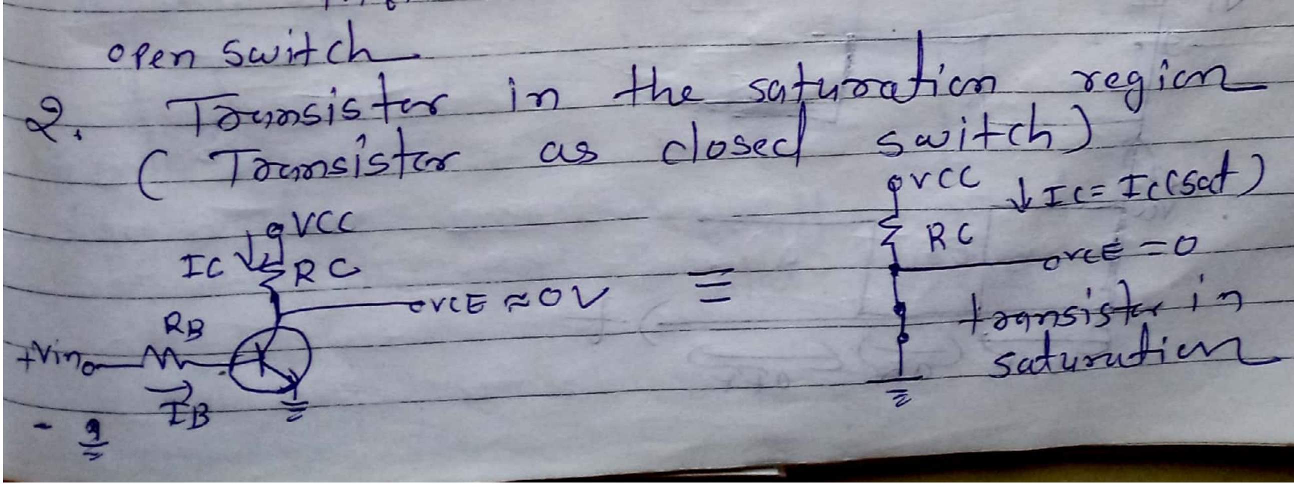
$$V_{CC} = I_C R_C + V_{CE}$$

$$I_C = 0$$

$$V_{CC} = V_{CE}$$

So V_{CE} is high, $I_C = 0$. This shows that the resistance is infinite and transistor operates as open switch

2. Transistor in the saturation region (Transistor as closed switch)



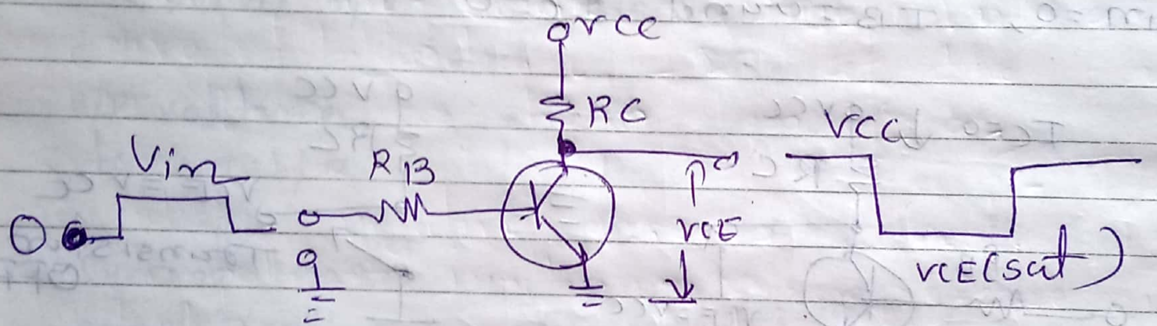
→ A high i/p voltage Vin is applied at the base.

→ The value of Vin and resistance R_B are adjusted such that a large I_B flows. This will saturate the transistor

$$I_B \geq \frac{I_{C(sat)}}{\beta}$$

→ Both junctions are forward biased. The voltage drop V_{CE} is very small and I_C is very large.

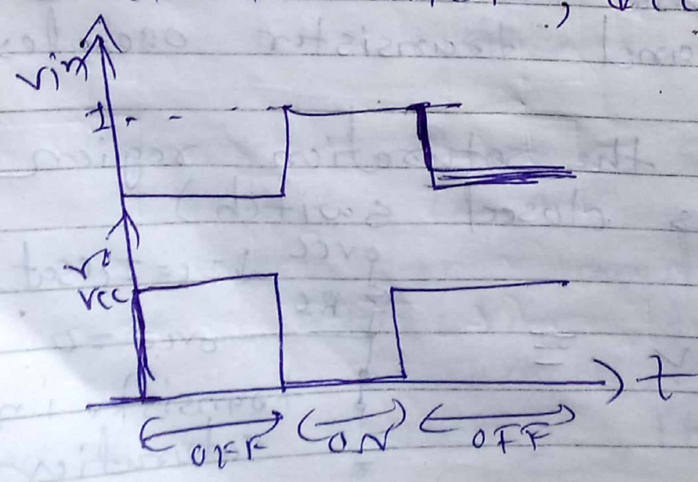
* Switching waveforms of an ideal transistor switch.



circuit diagram showing transistor biased to operate as a switch.

→ when i/p is low (0), transistor is off, it acts as an open switch and $V_{CE} \approx V_{CC}$

→ i/p voltage goes high, transistor is driven into saturation, it acts as a closed switch, $V_{CE} = V_{CE(sat)} = 0V$.



* Applications of
 1. in the logic circuit
 2. Temperature Controllers
 3. choppers used for DC motor control
 4. Multivibrators and schmitt trigger
 5. Relay drivers
 6. Stepper motor Controllers
 7. Timers
 8. SMPS and UPS.

Unit - 5

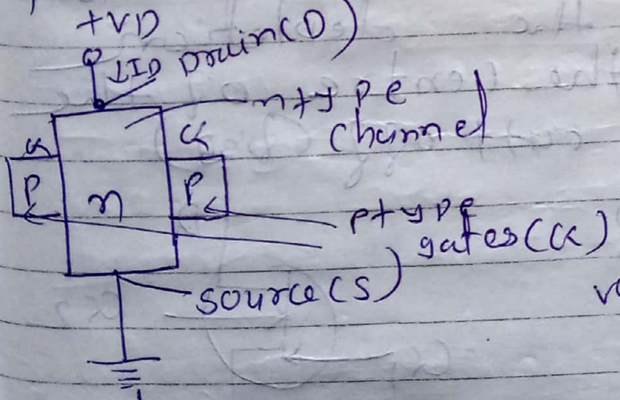
field effect Transistors (FET) and its biasing

→ Junction field effect transistors

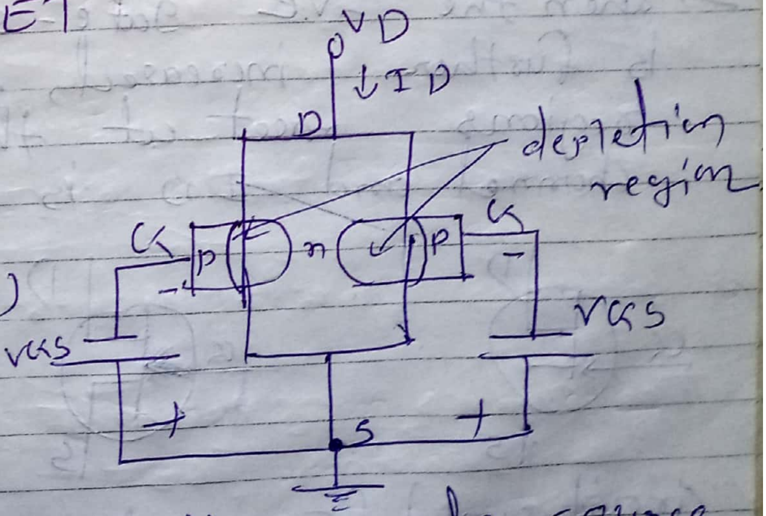
FET is a voltage operated device that can be used in amplifiers and switching circuits, same as BJT.

• Two categories of FET junction FETs and MOSFETS.

* N - channel JFET



No gate source bias voltage



small -ve gate source bias voltage