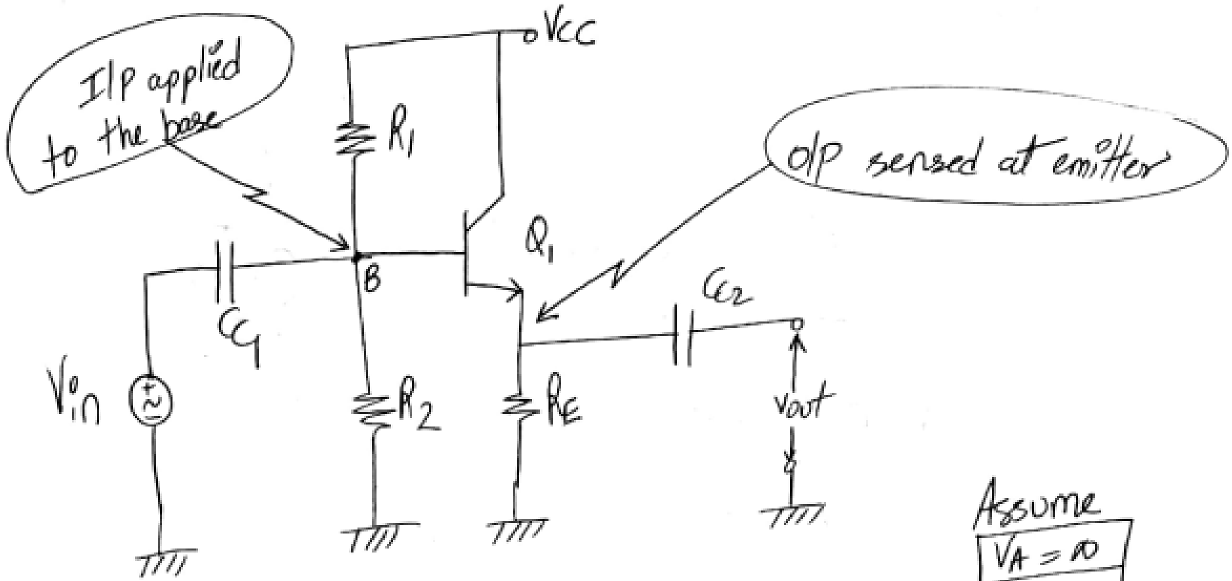
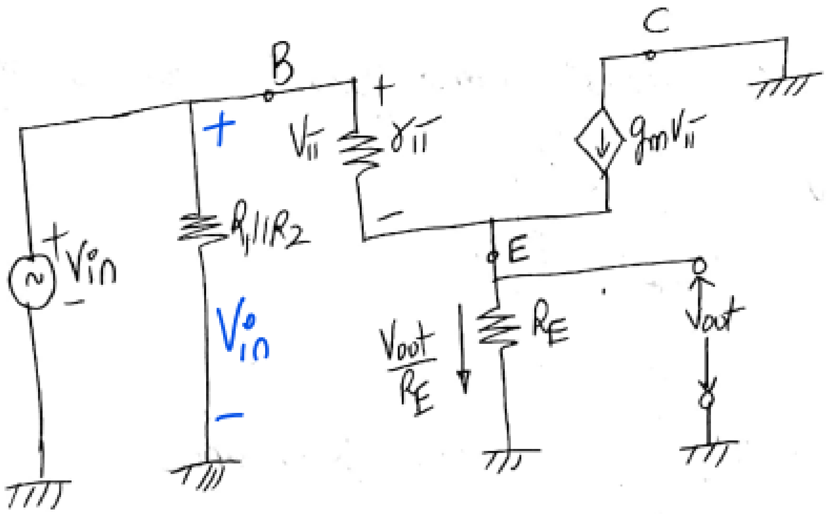
# Common Collector BJT amplifier

## * Common-collector amplifier (npn BJT) (Emitter follower)




Assume
$V_A = \infty$
ie $r_o = \infty$

## Small-signal voltage gain: $A_v$




ckt(c): Small-signal equivalent ckt of CC ampl$^r$

From ckt(c), apply KVL to B-E loop,

$V_{in} = V_\pi + V_{out}$ ie $\boxed{V_\pi = V_{in} - V_{out}}$ — (1)

KCL at 'E' node, gives

$$\frac{V_\pi}{r_\pi} + g_m V_\pi = \frac{V_{out}}{R_E}$$

$$\frac{V_{in} - V_{out}}{r_\pi} + g_m (V_{in} - V_{out}) = \frac{V_{out}}{R_E} \qquad (\text{From } ①)$$

$$\frac{V_{in}}{r_\pi} + g_m V_{in} = \frac{V_{out}}{R_E} + g_m V_{out} + \frac{V_{out}}{r_\pi}$$

$$V_{in}\left(\frac{1}{r_\pi} + g_m\right) = V_{out}\left[\frac{r_\pi + g_m r_\pi R_E + R_E}{r_\pi R_E}\right]$$

$$V_{in}\left(\frac{1 + g_m r_\pi}{\cancel{r_\pi}}\right) = V_{out}\left[\frac{r_\pi + g_m r_\pi R_E + R_E}{\cancel{r_\pi} R_E}\right]$$

$$r_\pi = \frac{\beta}{g_m}$$

But, $g_m r_\pi = \beta$

$$V_{in}(1+\beta) = V_{out}\left[\frac{r_\pi + (1+\beta)R_E}{R_E}\right]$$

$$\boxed{\frac{V_{out}}{V_{in}} = \frac{R_E(1+\beta)}{r_\pi + (1+\beta)R_E}}$$

$\div$ & $\times$ $N^r$ & $D^r$ by $(1+\beta)$

$$\frac{r_\pi}{1+\beta} \approx \frac{r_\pi}{\beta} = \frac{1}{g_m}$$

$$\frac{V_{out}}{V_{in}} = \frac{R_E}{\frac{r_\pi}{(1+\beta)} + R_E}$$

ie $\frac{V_{out}}{V_{in}} \simeq \boxed{\frac{R_E}{\frac{1}{g_m} + R_E} = A_v}$

$$\boxed{A_v = \frac{R_E}{\frac{1}{g_m} + R_E}}$$

↳ CC ampl$^r$

let's verbalize the gain formula,

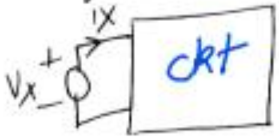
$$\boxed{A_v = \frac{\text{Resistance tied bet}^n \text{ Emitter \& ac ground}}{\frac{1}{g_m} + \text{resistance tied bet}^n \text{ Emitter \& ac gnd}}}$$

$A_v = \frac{g_m R_E}{1 + g_m R_E}$ is always very close to 1, but always less than unity

ie $\boxed{A_v \le 1}$ for a CC amplifier or emitter follower

- There is no phase difference bet$^n$ the I/p & o/p signals in an emitter follower.
- In this amplifier, i/p signal changes in the base follows the changes in the emitter. Hence, the name of circuit is "emitter follower".

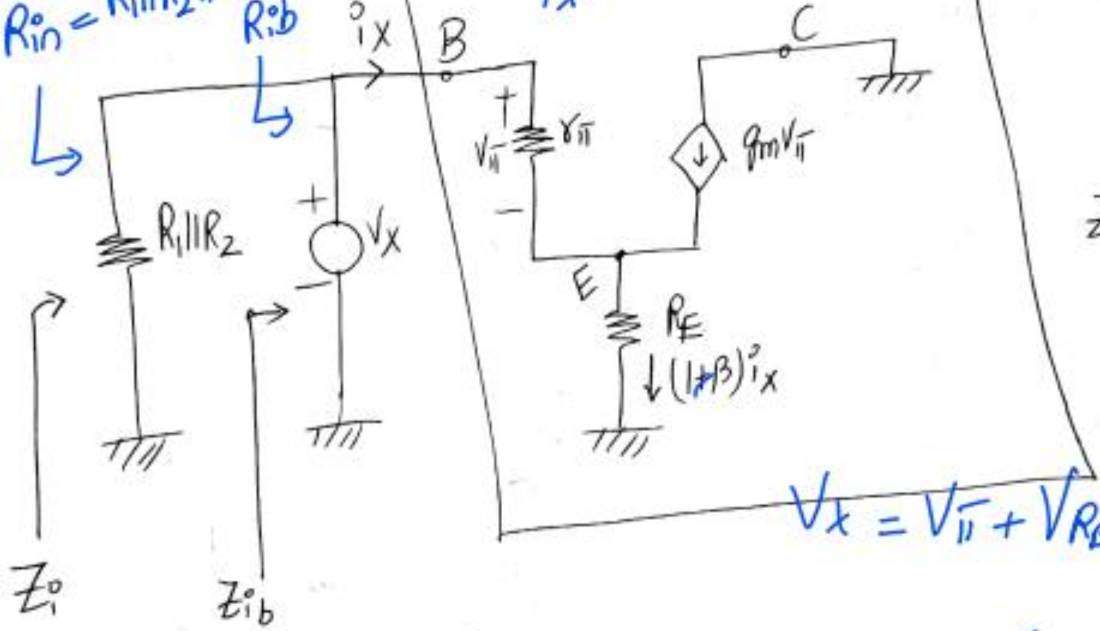
## I/P impedance : $Z_i$ ($R_{in}$)




Redrawing ckt (c),

$R_{ib} = \frac{V_x}{i_x}$

$R_{in} = R_1 \| R_2 \| R_{ib}$




$Z_{ib} = \frac{V_x}{i_x}$

$V_x = V_\pi + V_{R_E}$

From ckt, $V_\pi = i_x r_\pi$ ✓

$i_E = (1+\beta) i_B$

ie $g_m V_\pi = g_m i_x r_\pi$

Current through 'B' is $i_x$

current through 'E' is $(1+\beta) i_x$

KVL at B-E loop, gives

$V_x = V_\pi + \text{voltage drop across } R_E$

$V_x = i_x r_\pi + \underline{(1+\beta) i_x R_E}$

or $Z_{ib}$ / $R_{ib}$ $= \frac{V_x}{i_x} = r_\pi + (1+\beta) R_E$

"$r_\pi$"

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$R_{in} = R_1 || R_2 || R_{ib}$ "high"

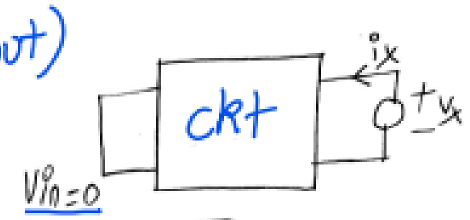
$$\boxed{Z_i = R_1 || R_2 || [r_\pi + (1+\beta)R_E]}$$

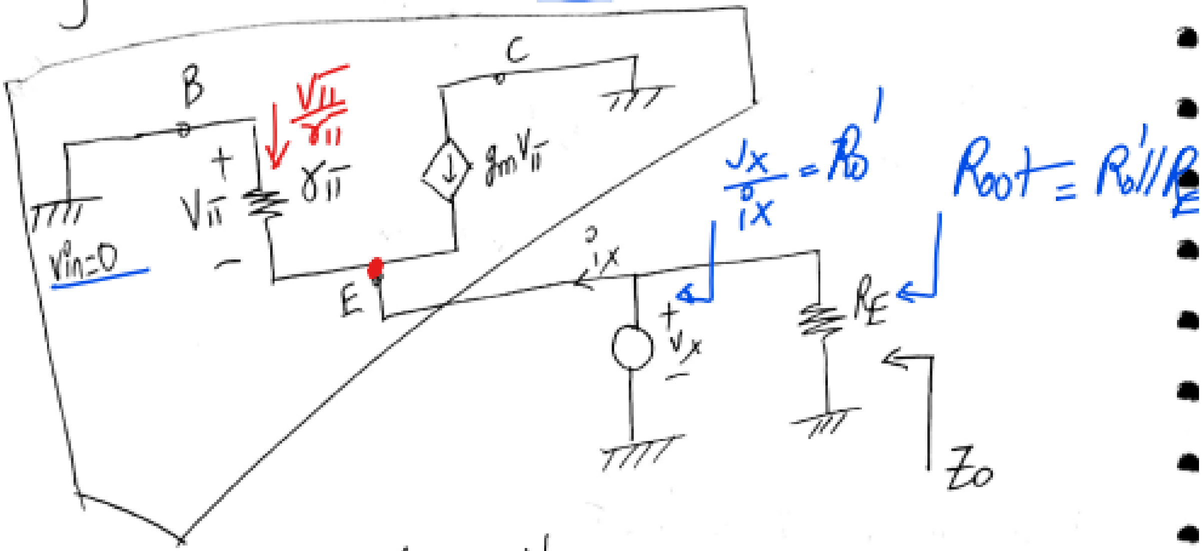
$R_{in}$ or $Z_i$

high i/p impedance in CC ampl$^r$

* Output impedance : $Z_o$ ($R_{out}$)

Redrawing ckt(c) with $V_{in}=0$




From above ckt, $V_\pi = -V_x$

KCL at 'E' node gives,

$$\frac{V_\pi}{r_\pi} + g_m V_\pi + i_x = 0$$

$$-\frac{V_x}{r_\pi} - g_m V_x = -i_x$$

$$V_x\left(\frac{1}{r_\pi} + g_m\right) = i_x$$

$$i_x = V_x \left( \frac{g_m r_\pi + 1}{r_\pi} \right) \qquad g_m r_\pi = \beta$$

$$i_x = V_x \left( \frac{1+\beta}{r_\pi} \right) \qquad 1+\beta \approx \beta$$

$$i_x = V_x \left( \frac{\beta}{r_\pi} \right) \qquad \frac{\beta}{r_\pi} = g_m$$

$$i_x = V_x \, g_m$$

$$\boxed{\frac{V_x}{i_x} = \frac{1}{g_m}}$$

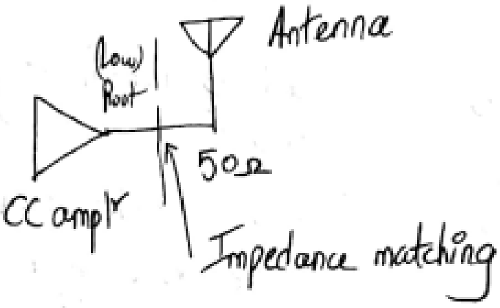
$$A_v \approx 1$$
$$R_{in} \approx \text{high}$$
$$R_{out} \approx \text{low}$$

$$R_{out} = \frac{1}{g_m} \,||\, R_E$$

$$\therefore \boxed{Z_o = R_E \,||\, \frac{1}{g_m}}$$ Low output impedance

## Application of CC amplifier :-

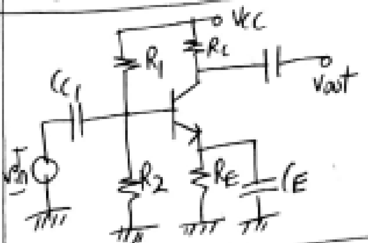
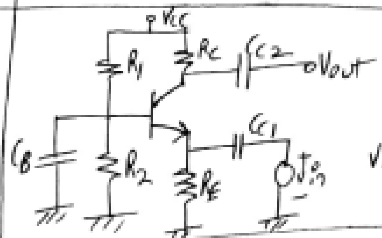
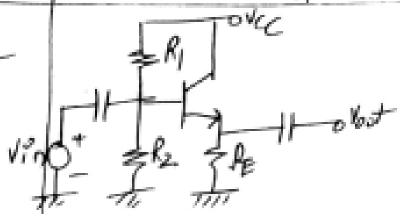
- It is used as a buffer betn ampl^r and o/p stage
- It is used to drive a low impedance antenna or speaker



# Comparison of CE, CB, CC amplifier



## # Comparison of CE, CB and CC amplifiers

| | Common-emitter | Common-base | Common-collector |
|---|---|---|---|
| 1. Circuit |  |  |  |
| 2. I/P applied to | Base terminal | Emitter terminal | Base terminal |
| 3. O/P sensed at | Collector terminal | Collector terminal | Emitter terminal |
| 4. Voltage gain | $A_v = -g_m R_C$ <br> $\boxed{\text{high}}$ | $A_v = g_m R_C$ <br> $\boxed{\text{high}}$ | $A_v = \frac{g_m R_E}{1+g_m R_E} \approx 1$ <br> $\boxed{\text{low}}$ |
| 5. I/P impedance | $Z_i = R_1 \| R_2 \| r_\pi$ <br> $\boxed{\text{medium}}$ | $Z_i = \frac{1}{g_m} \| R_E$ <br> $\boxed{\text{low}}$ | $Z_i = R_1 \| R_2 \| [r_\pi + (1+\beta)R_E]$ <br> $\boxed{\text{v.high}}$ |
| 6. O/P impedance | $Z_o = R_C$ <br> $\boxed{\text{medium}}$ | $Z_o = R_C$ <br> $\boxed{\text{medium}}$ | $Z_o = \frac{1}{g_m} \| R_E$ <br> $\boxed{\text{low}}$ |
| 7. Phase of O/P signal | Out of Phase with I/P signal | In phase with I/P signal | In phase with I/P signal |
| 8. Application | 1) Common used as inverting voltage amplifiers | 1) used as non-inverting ampl^r <br> 2) used as a ckt which can be driven by a low impedance source | 1) used as a voltage buffer <br> 2) used to drive a low impedance load (eg antenna or speaker) |