BJT - Mach khuech dai su dung BJT

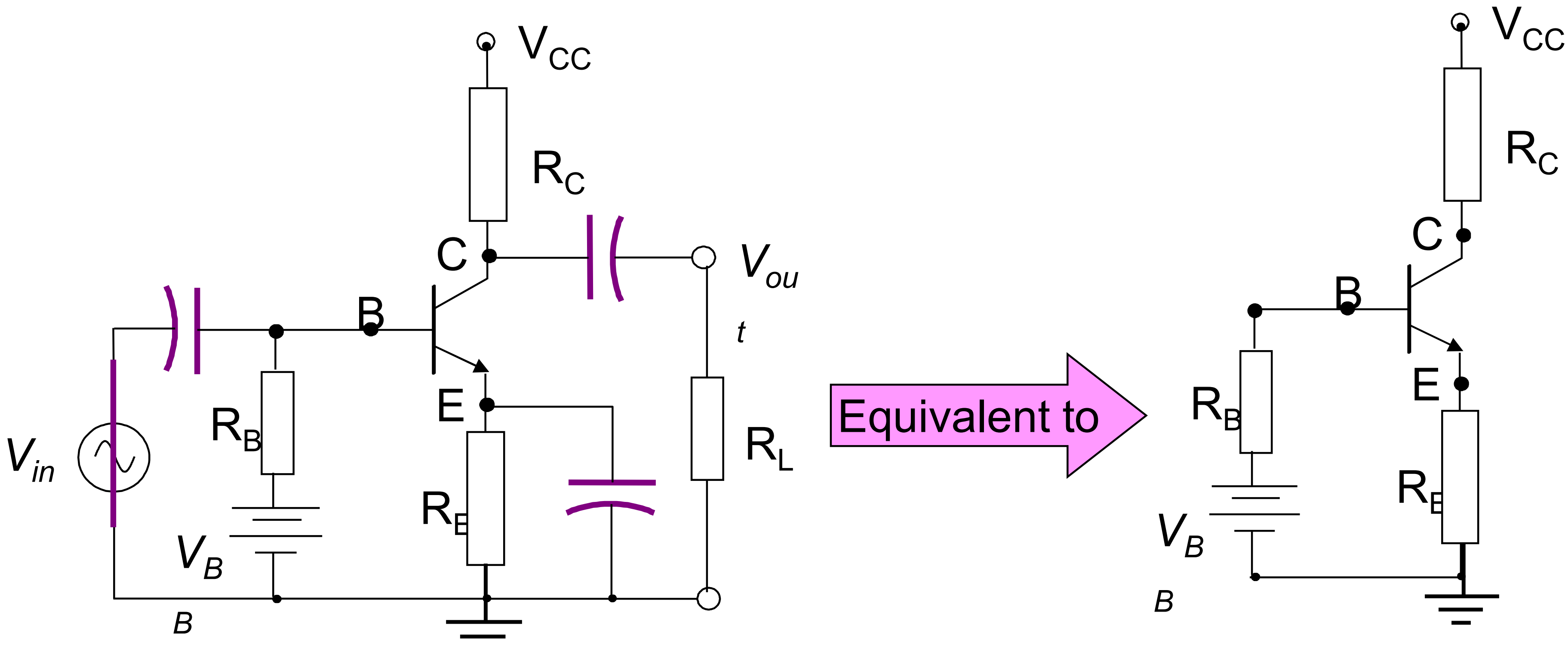
Điện tử tương tự (Trường Đại học Bách khoa Hà Nội)

Phân tích DC cho mạch DC (DC analysis)

- **Để chuyển đổi một mạch KĐ sang mạch DC thì:.**
  1. **Cho các nguồn AC bằng ZERO.**
  2. **Loại bỏ các tụ.**
  3. **Ngắn mạch cuộn dây.**
  4. **Vẽ lại mạch.**
- **Dùng mạch biến đổi này (DC equivalent circuit) để tính các giá trị định thiên 1 chiều I_B & I_C và V_{CE}.**

KĐ CE amplifier

Mạch tương đương DC:

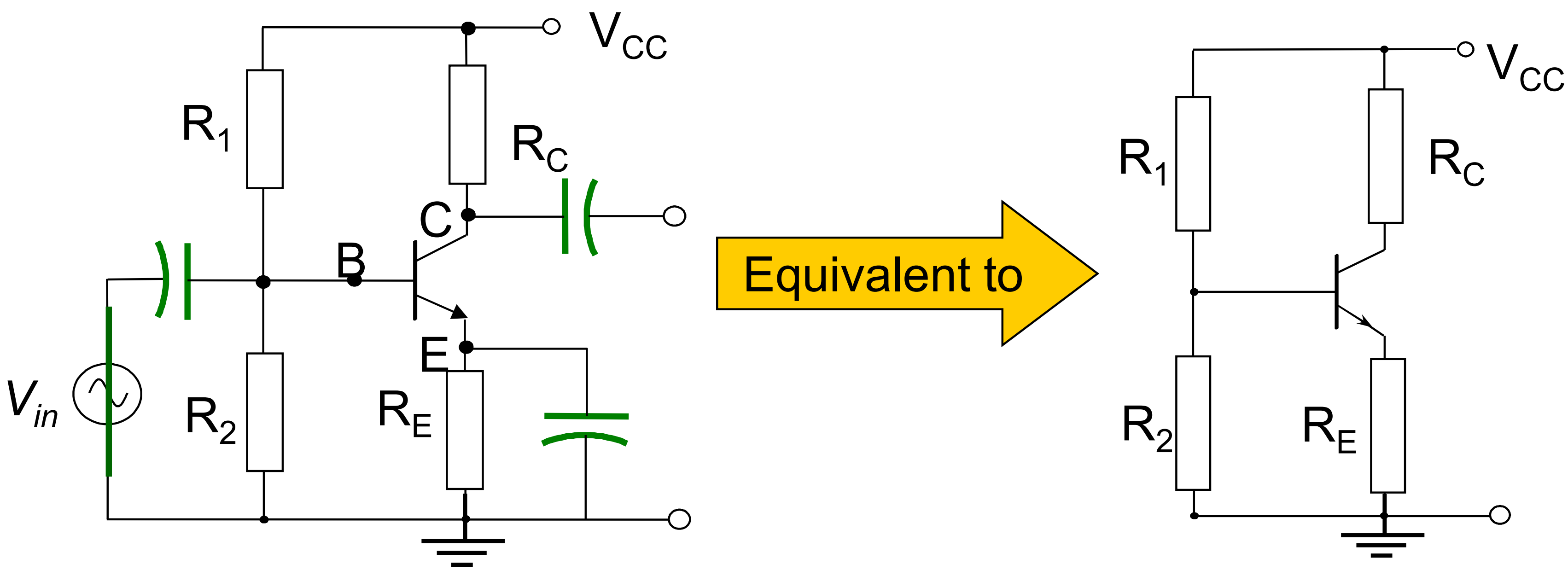


Mạch tương đương DC (cont'd)

KĐ CE

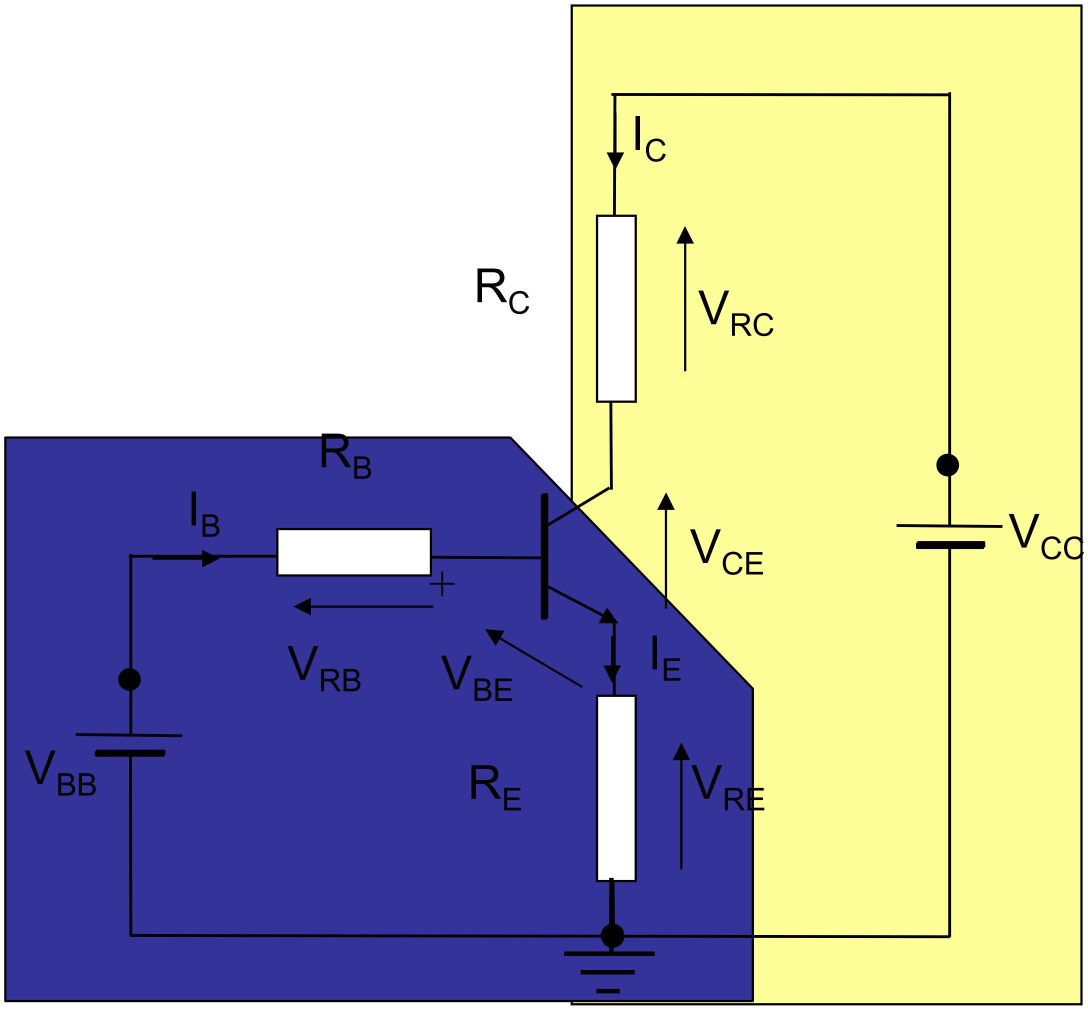
(voltage divider bias)

Mạch tương đương DC:



Phân tích 1 chiều của mạch KĐ CE

The purpose of the dc biasing circuit is to set up the initial dc values of I_B, I_C, and V_{CE}



DC bias circuit of CE amplifier

- **Có 2 vòng mạch:**
  --- mạch đầu vào
  --- mạch đầu ra
- **Mạch đầu vào gồm V_{BB}, R_B, V_{BE} và R_E**
- **KVL**
  $$V_{BB} = V_{RB} + V_{BE} + V_{RE}$$
  $$V_{BB} = R_B I_B + V_{BE} + R_E I_E$$
- **Mạch ra gồm V_{CC}, R_C, V_{CE} và R_E**
- **KVL (phương trình tải DC)**
  $$V_{CC} = V_{RC} + V_{CE} + V_{RE}$$
  $$V_{CC} = R_C I_C + V_{CE} + R_E I_E$$

DC biasing circuit (cont'd)

- Since the transistor is operating in the active region, the emitter current can be expressed by:

$$I_E = I_C + I_B = \beta_{DC}\, I_B + I_B = (\beta_{DC} + 1)\, I_B \approx \beta_{DC}\, I_B$$

For β_{DC} is larger than ($\geq$)50, we usually assume that:

$$I_E = I_C = \beta_{DC}\, I_B$$

Substitute I_E into the biasing equation, we have:

$$V_{BB} = R_B\, I_B + V_{BE} + R_E\, (\beta_{DC}\, I_B)$$
$$V_{BB} - V_{BE} = (R_B + \beta_{DC}\, R_E)\, I_B$$

Or $\boxed{I_B = (V_{BB} - V_{BE}) / (R_B + \beta_{DC}\, R_E)}$ This is the biasing base current.

- $\boxed{I_C = \beta_{DC}\, I_B}$ --- Transistor operates in the active region

- Applying KVL around the output circuit we obtain the dc load line equation:

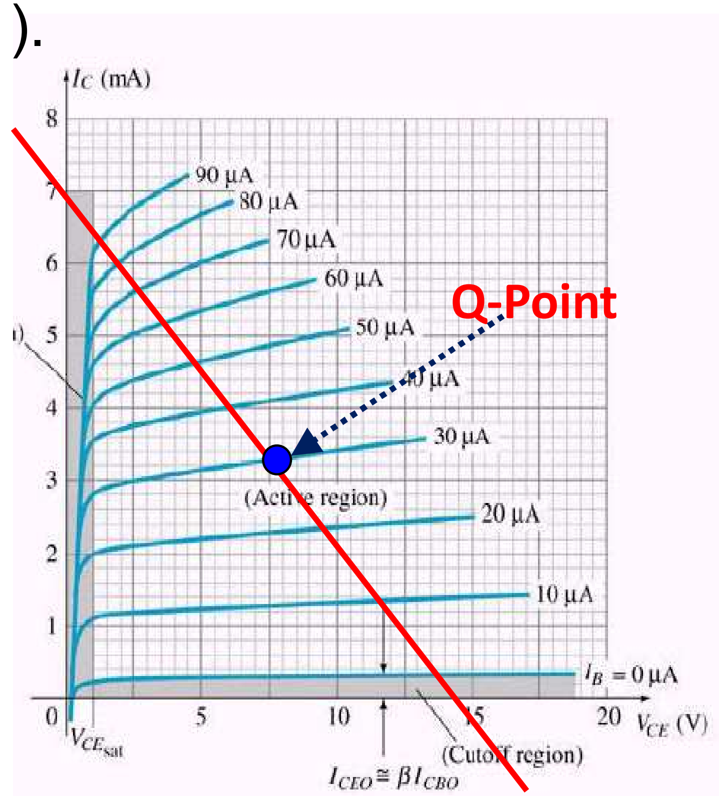
$$V_{CC} = R_C\, I_C + V_{CE} + R_E\, I_E$$ *For $\beta_{DC} \geq 50$, assume $I_E = I_C$,*

$\boxed{V_{CE} = V_{CC} - (R_C + R_E)\, I_C}$ This is the transistor collector-emitter voltage.

- The operating point (Q point) of the transistor is at (V_{CE}, I_C).

Điểm Q (Q-point)

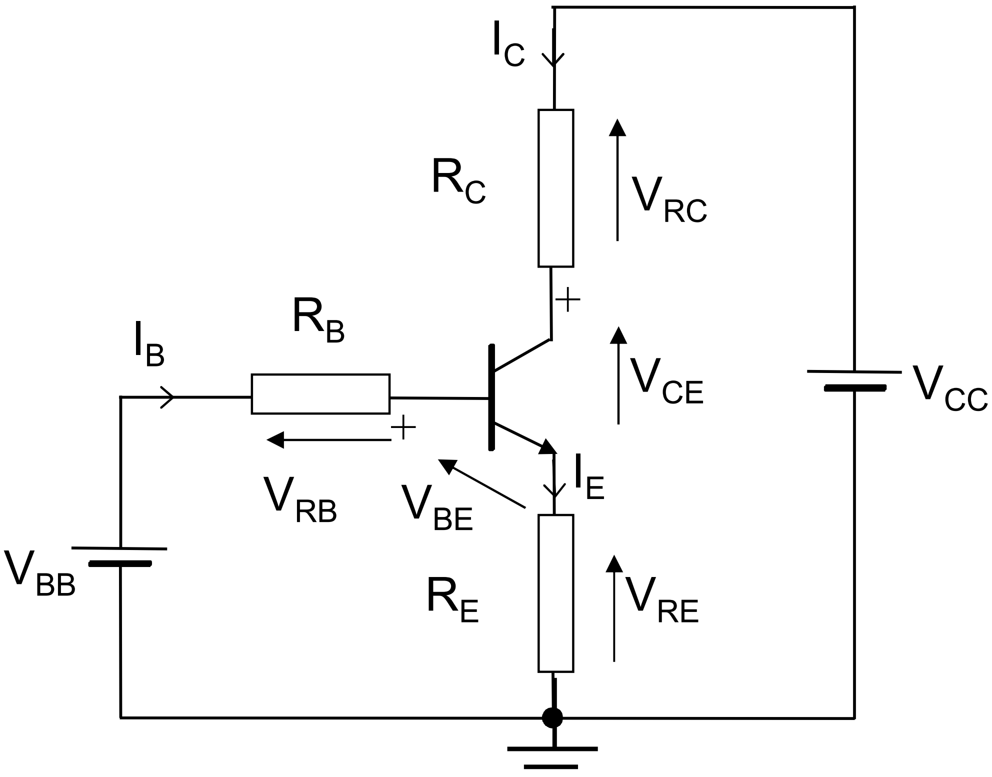
- I_C và V_{CE} xác định điểm làm việc Q (V_{CEQ}, I_{CQ}).
  - Các tên gọi khác:
    - Biasing point
    - Quiescent point
    - Operating point (OP)
    - DC point



- Điểm Q chỉ ra dòng ra 1 chiều $I_{C(DC)}$ và áp ra 1 chiều $V_{CE(DC)}$ *khi chưa đặt áp xoay chiều AC vào đầu vào.*

VD

Transistor loại Si (β_{DC} = 200) hình dưới được dùng làm mạch KĐ có R_B = 10kΩ, V_{BB} = 10V, R_C = 100Ω, R_E = 680Ω và V_{CC} = 20V. Xác định Q (V_{CEQ}, I_{CQ})



Đáp án

Step 1: Xác định I_B.

Áp dụng KVL cho mạch đầu vào:

$$V_{BB} = R_B I_B + V_{BE} + \beta_{DC} I_B R_E$$

$$10V = 10k\Omega\ I_B + 0.7V + 200 \times 680\ I_B$$

$$I_B = (10V - 0.7V) / (10k\Omega + 200 \times 680) = 63.7\mu A$$

Step 2: TìmI_C.

$$I_C = \beta_{DC}\ I_B = 200 \times 63.7\ \mu A = 12.74\ mA$$

Step 3: Tìm V_{CE}.

Áp dụng KVL cho mạch đầu ra

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

$$20V = 100\Omega I_C + V_{CE} + 680\Omega I_E$$

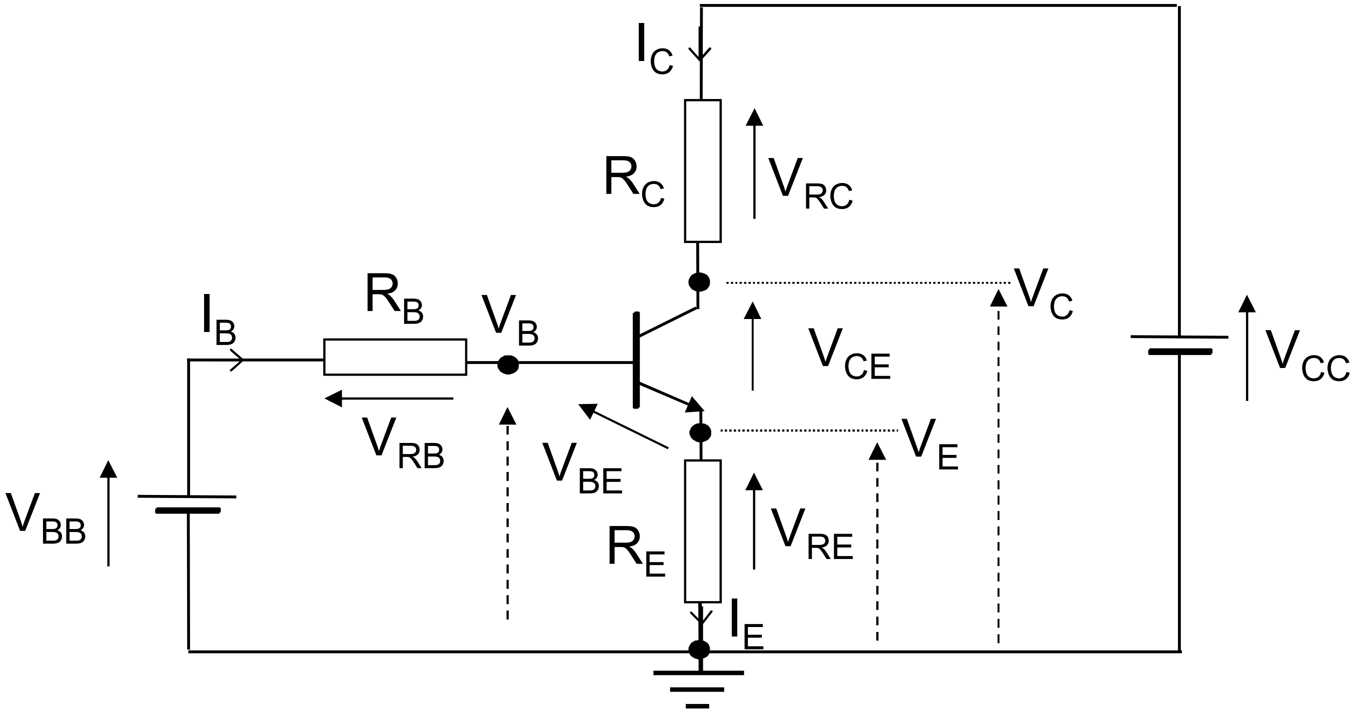
Vì β_{DC} lớn, $I_E = I_C$

$$V_{CE} = 20V - 100xI_C - 680I_E$$

$$V_{CE} = 20V - 100x12.74mA - 680 \times 12.74mA = 10.06V$$

Vậy điểm làm việc Q *(V_{CEQ} = 10.06V, I_{CQ} = 12.74mA).*

Thê tại các cực B, C, R



- **V_B:**

$$V_B = V_{BB} - V_{RB} = V_{BB} - I_B R_B$$
Or $V_B = V_{RE} + V_{BE} = I_E R_E + V_{BE}$

- **V_E:**

$$V_E = I_E R_E$$
Or $V_E = V_{CC} - V_{RC} - V_{CE} = V_{CC} - I_C R_C - V_{CE}$
Or $V_E = V_{BB} - V_{RB} - V_{BE} = V_{BB} - I_B R_B - V_{BE}$

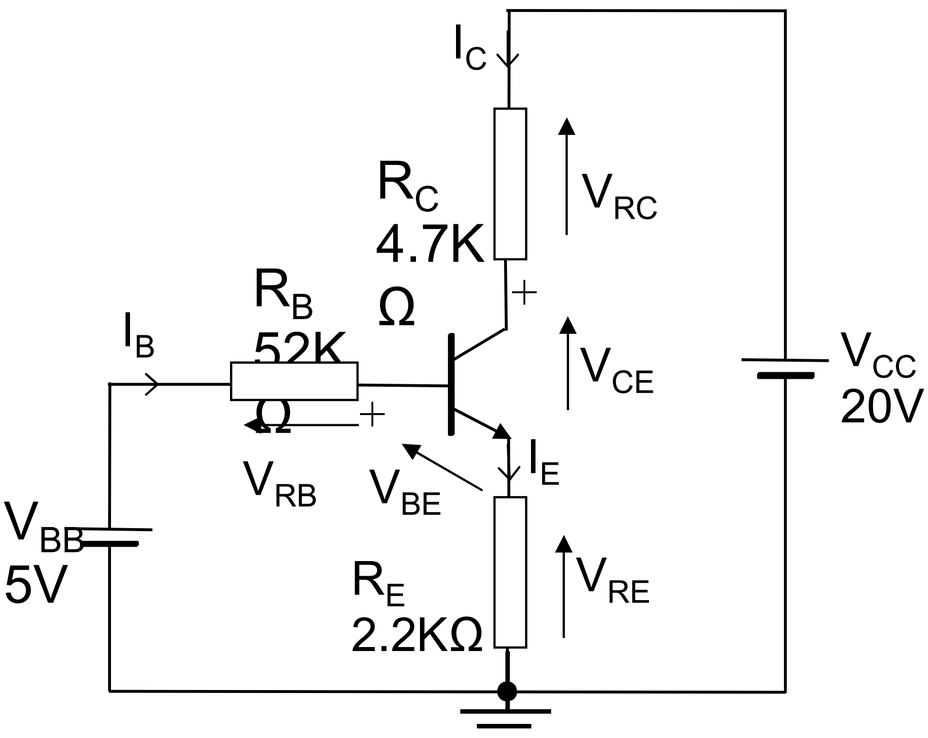
- **V_C:**

$$V_C = V_{CC} - V_{RC} = V_{CC} - I_C R_C$$
Or $V_C = V_{RE} + V_{CE} = I_E R_E + V_{CE}$

BT 1

Tìm I_B, I_C, V_{CE} và xác định vùng làm việc và điểm Q của transistor.

$\beta_{DC}=100$



The Q-point of the transistor is at:
(V_{CEQ} = 9.098V, I_{CQ} = 1.58mA).

Solution

Step 1: Determine I_B.

Apply KVL around the input circuit:

$V_{BB} = R_B I_B + V_{BE} + \beta_{DC} I_B R_E$

$5V = 52k\Omega I_B + 0.7V + 100 \times 2.2K\Omega\, I_B$

$I_B = (5V - 0.7V)/(52k\Omega + 100 \times 2.2K\Omega)$

$= 15.8\mu A$

Step 2: Determine the collector current I_C.

$I_C = \beta_{DC} I_B = 100 \times 15.8\mu A = 1.58\ mA$

Step 3: Determine V_{CE}.

Applying KVL around the output circuit

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

$20V = 4.7K\Omega I_C + V_{CE} + 2.2K\Omega I_E$

Since β_{DC} is large, $I_E = I_C$

$V_{CE} = 20V - 4.7K\Omega I_C - 2.2K\Omega I_C$

$V_{CE} = 20V - 4.7K\Omega \times 1.58mA - 2.2K\Omega \times 1.58mA = 9.098V$

Because $V_{BE}=0.7V>0$ --BE forward biased

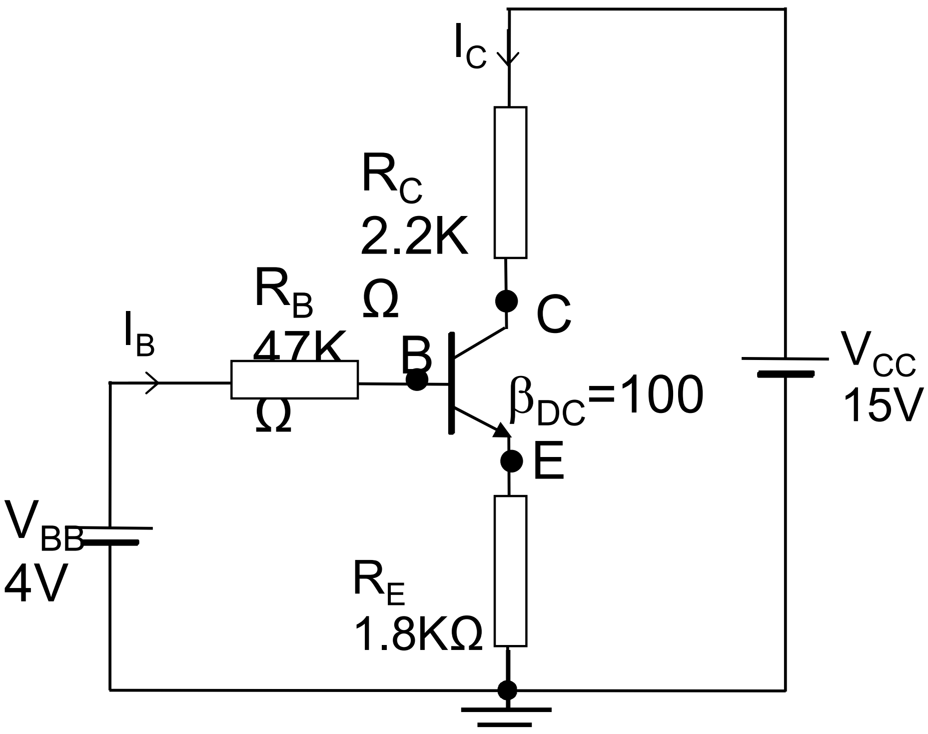
$\therefore V_{BC}=V_{BE}-V_{CE}=0.7-9.098=-8.398V<0$

---BC reverse biased

$\therefore$this transistor is in active region

BT 2

Timf V_B, V_C, V_E.



Solution:

Step 1: find I_B

$I_B = (V_{BB} - V_{BE}) / (R_B + \beta_{DC} R_E)$

$= (4-0.7)/(47K\Omega+100\times 1.8K\Omega)$

$=14.54\mu A$

Step 2: find V_B

$V_B = V_{BB} - I_B R_B = 4-14.5\ \mu A \times 47K\Omega = 3.32V$

Step 3: find I_C

$I_C = \beta_{DC} I_B = 100 \times 14.5\ \mu A = 1.45mA$

Step 4: find V_C

$V_C = V_{CC} - I_C R_C = 15 - 1.45mA \times 2.2K\Omega = 11.81V$

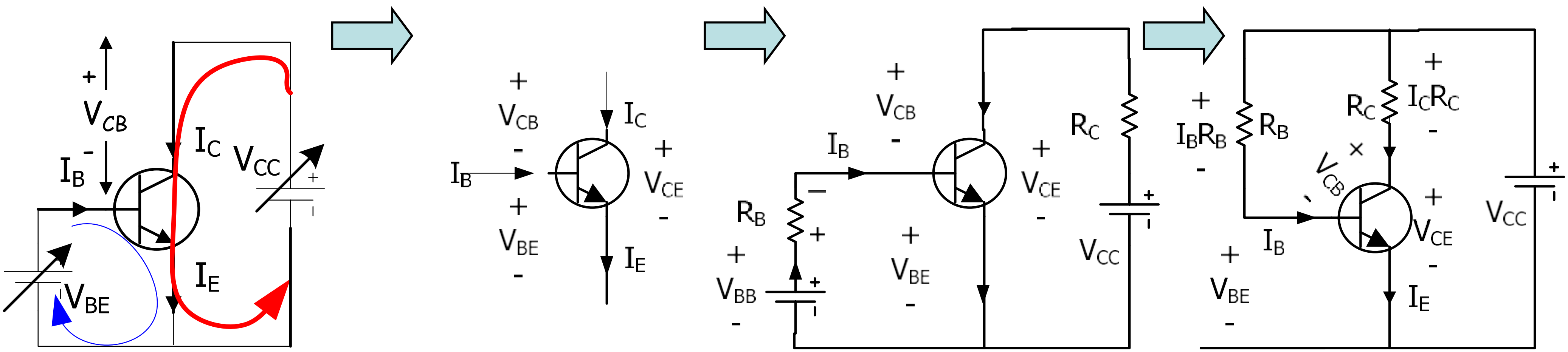
Step 5: find V_E

Because $\beta_{DC} > 50$, $I_E = I_C$

$\therefore V_E = I_E R_E = I_C R_E = 1.45mA \times 1.8K\Omega = 2.61V$

Các mạch định thiên cho BJT

1. Mạch định thiên/phân cực BJT



$V_{CE} = V_{CB} + V_{BE} = V_{CC}$

Development of Biasing circuit for BJT by one battery

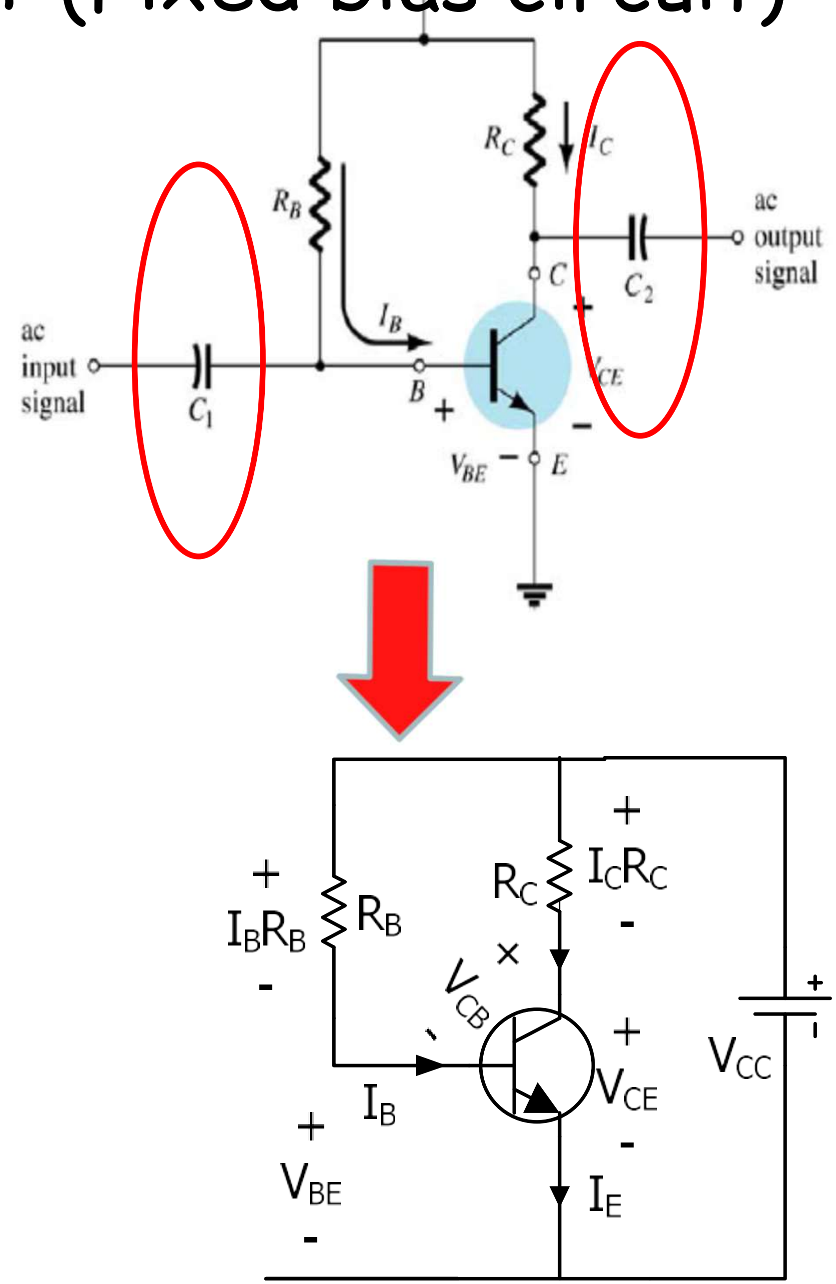
Forward bias $V_{BE} = V_{CC} - I_B R_B$

Reverse bias $V_{CB} = V_{CC} - I_C R_C - V_{BE}$

2. Phân cực cố định cho BJT (Fixed bias circuit)

2.1. Cho npn-BJT

- Loại (CE)
- Nhược điểm
  - ➢Không ổn định – because it is too dependent on β and produce width change of Q-point
  - ➢Để tăng tính ổn định, thêm R_E.

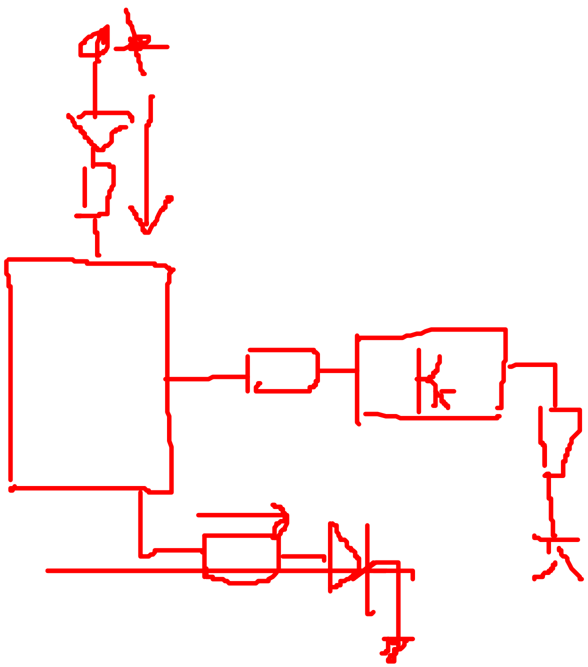


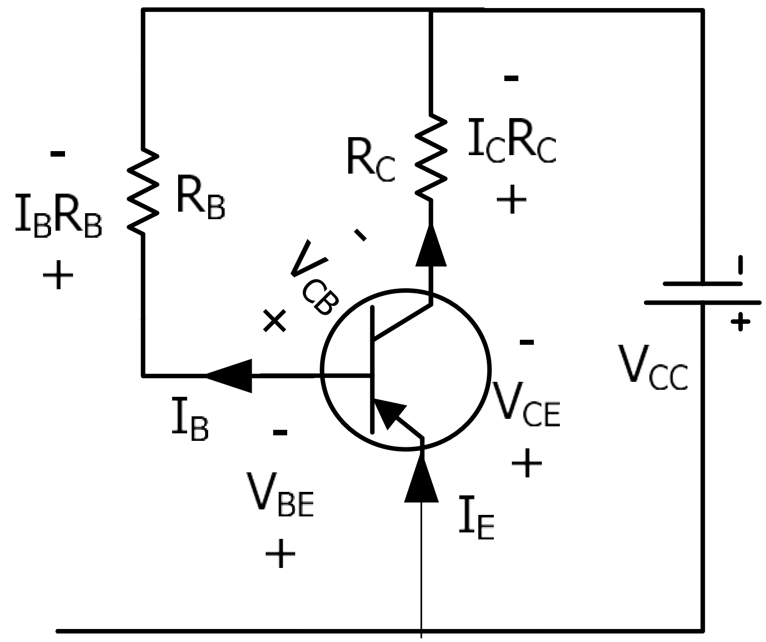
Fixed Bias Method

- Solve the circuit using HVK
- 1st step: Locate capacitors and replace them with an open circuit
- 2nd step: Locate 2 main loops which;
  - ➢ BE loop
  - ➢ CE loop

Fixed bias npn-BJT has I_B obtained by R_B connected to V_{CC}

2.2 Loại pnp-BJT



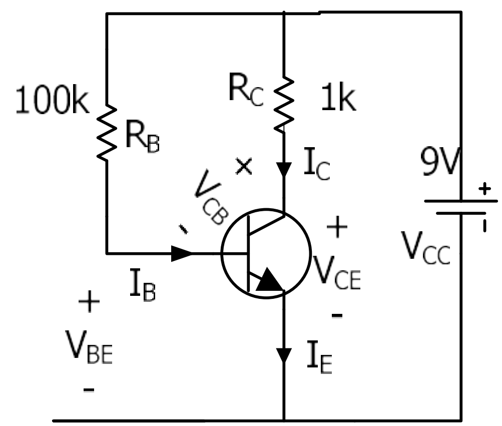


Fixed Bias Method

So với npn-BJT chỉ có V_{CC} đảo chiều

2.3 Phân tích mạch phân cực cố định cho BJT

VD:
Mạch BJT có V_{CC}=9V, β=50 , R_B=100kΩ, R_C=1kΩ . Khi PCT V_{BE}=0.7V, tìm I_B, I_C, I_E,V_{CE}, và áp PCN V_{CB}.



[redacted]

$$9 = I_B \times 100k + 0.7 \Rightarrow I_B = \frac{9-0.7}{100k} = 0.083mA = \underline{\underline{83\mu A}}$$

$$I_C = \beta I_B = 50 \times 0.083mA = \underline{\underline{4.15mA}}$$

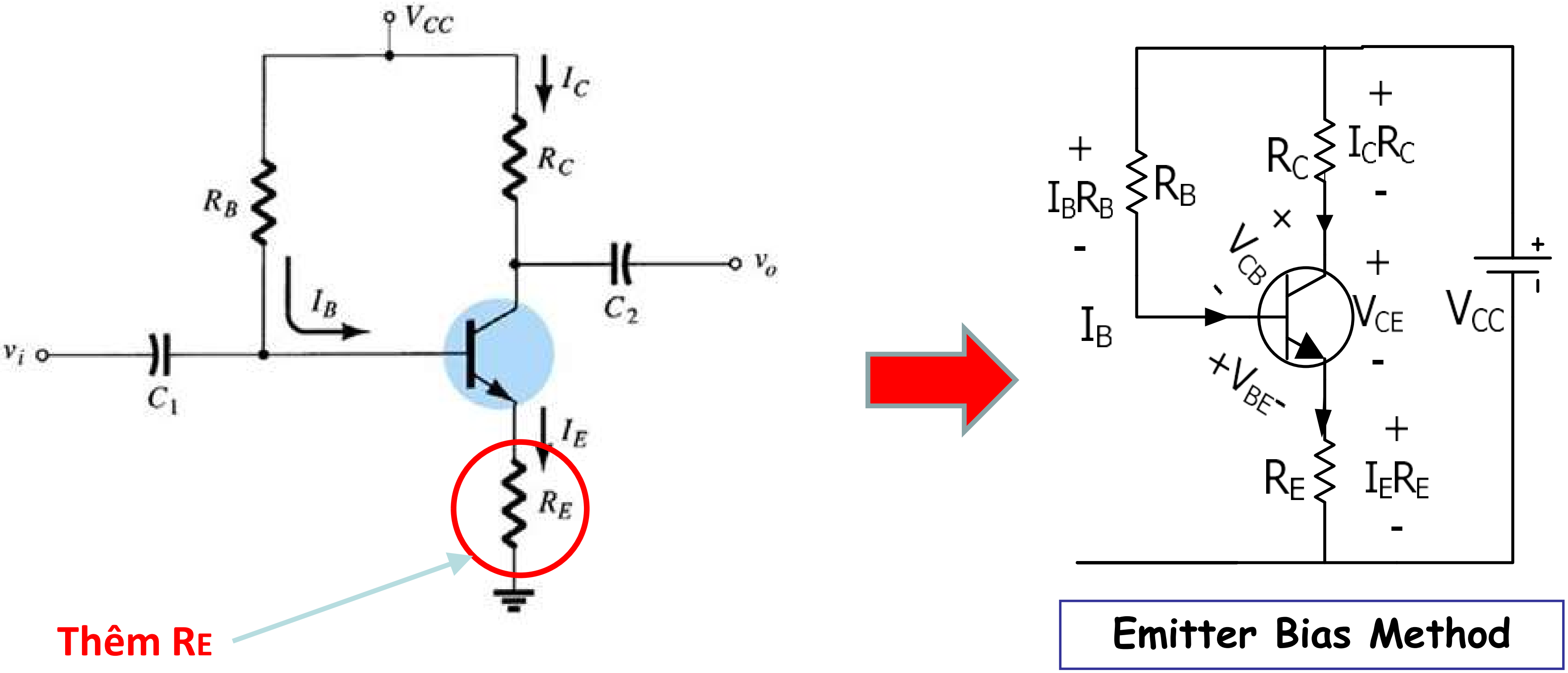
$$I_E = I_C + I_B = 4.15 + 0.083 = \underline{\underline{4.233mA}}$$

$$V_{CE} = 9 - \left(I_C \times 1k\right) = 9 - 4.15 = \underline{\underline{4.85V}}$$

$$V_{CE} = V_{CB} + 0.7 \Rightarrow V_{CB} = 4.85 - 0.7 = \underline{\underline{4.15V}}$$

3. Mạch phân cực E cho BJT (Emitter bias circuit)

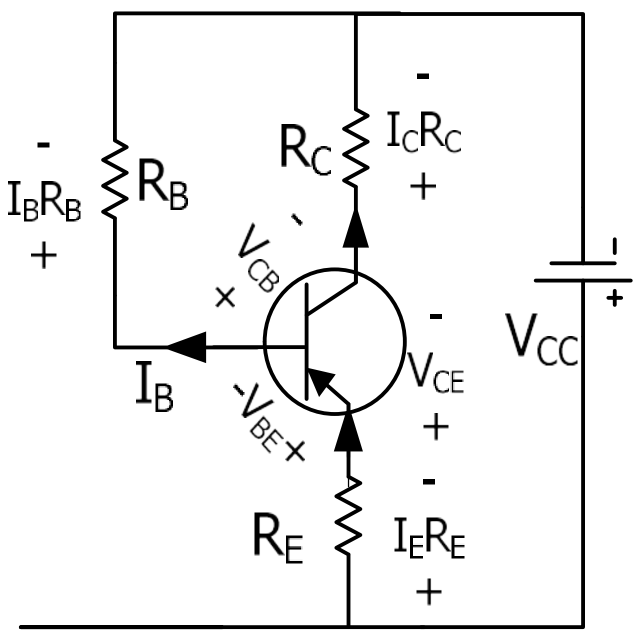
3.1 npn-BJT



Thêm RE để cải thiện tính ổn định

Emitter bias npn-BJT has I_B obtained by R_B connected to V_{CC} and R_E connected to Emitter for better stabilization of I_C

3.2 pnp-BJT



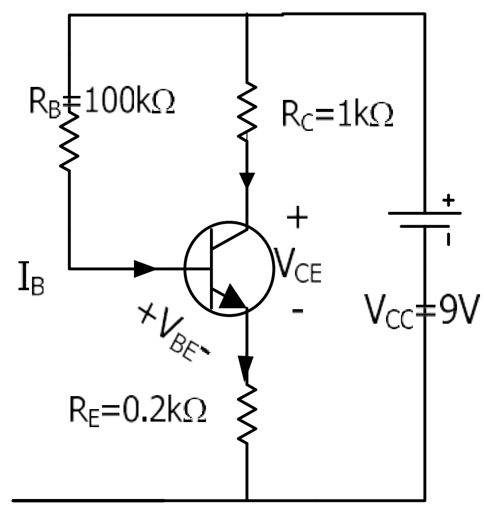
pnp Emitter Bias Method

So với npn-BJT chỉ có V_{CC} đảo chiều

3.3 Phân tích mạch định thiên E cho BJT

VD:

Mạch KĐ BJT có V_{CC}=9V, β=50 , R_B=100kΩ, R_C=1kΩ . R_E=0.2kΩ. Khi PCT V_{BE}=0.7V, tìm I_B, I_C, I_E,V_{CE}, và áp PCN V_{CB}.



$$9 = I_B \times 100k + 0.7 + \left(\left(50+1\right)I_B\right) \times 0.2k \Rightarrow \left[\text{taking } 1 << \beta\right]$$

$$I_B = \frac{9-0.7}{110k} = 0.0754mA = \underline{\underline{75.4\mu A}}$$

$$I_C = \beta I_B = 50 \times 0.0754mA = \underline{\underline{3.77mA}}$$

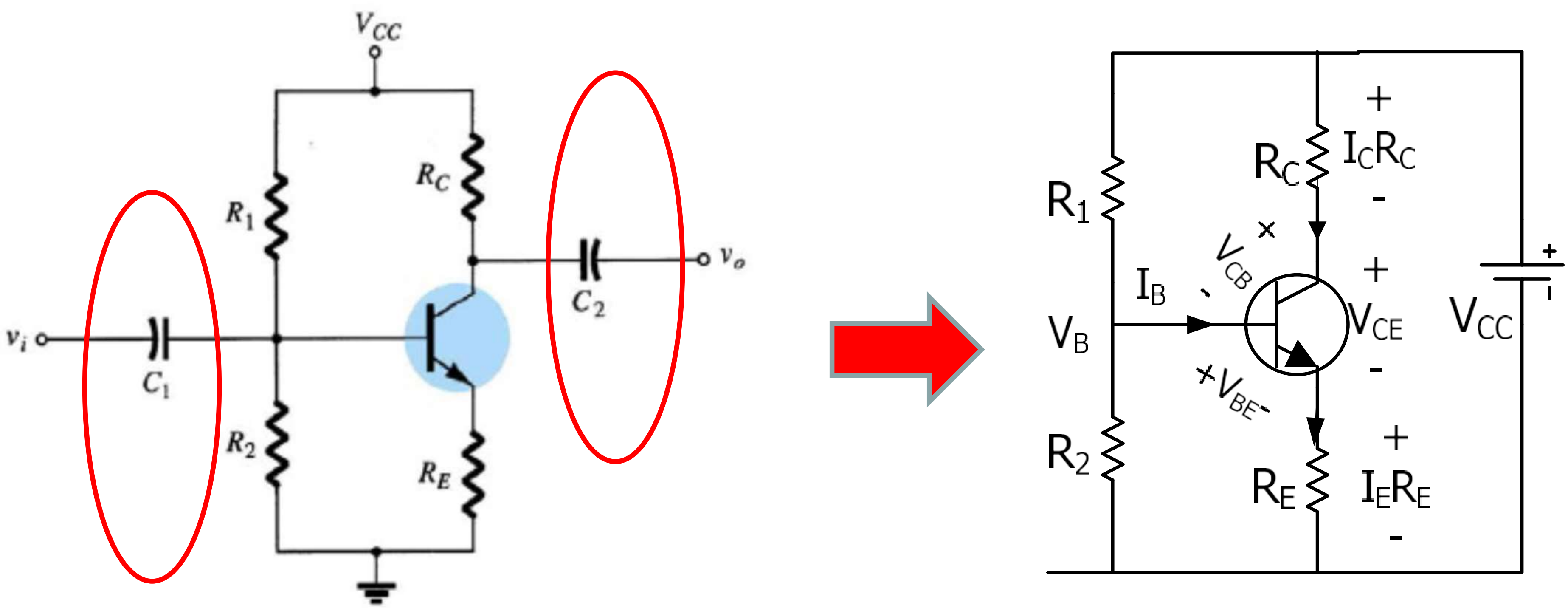
$$I_E = I_C + I_B = 3.77 + 0.0754 = \underline{\underline{3.84mA}}$$

$$V_{CE} = 9 - \left(\left(I_C\right) \times 1k + 0.2k\right) = \underline{\underline{4.476V}}$$

$$V_{CE} = V_{CB} + 0.7 \Rightarrow V_{CB} = 4.476 - 0.7 = \underline{\underline{3.776V}}$$

4. Mạch định thiên kiểu phân áp BJT (Voltage divider bias circuit)

4.1 npn-BJT

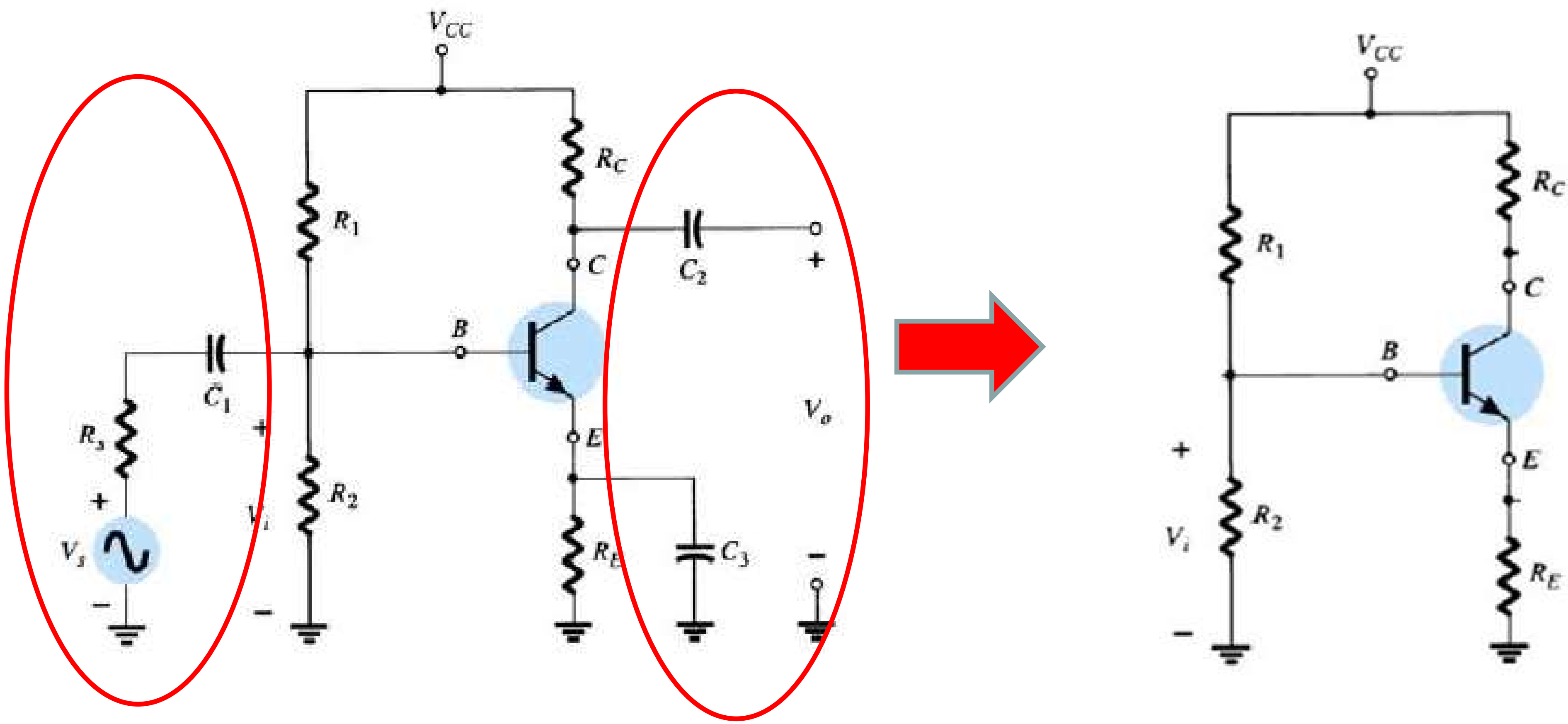


- **Khi phân tích DC, hở mạch tụ**

- Với mạch npn-BJT này, I_B có được qua phân áp dùng R_1 và R_2 còn R_E để cải thiện sự ổn định của I_C

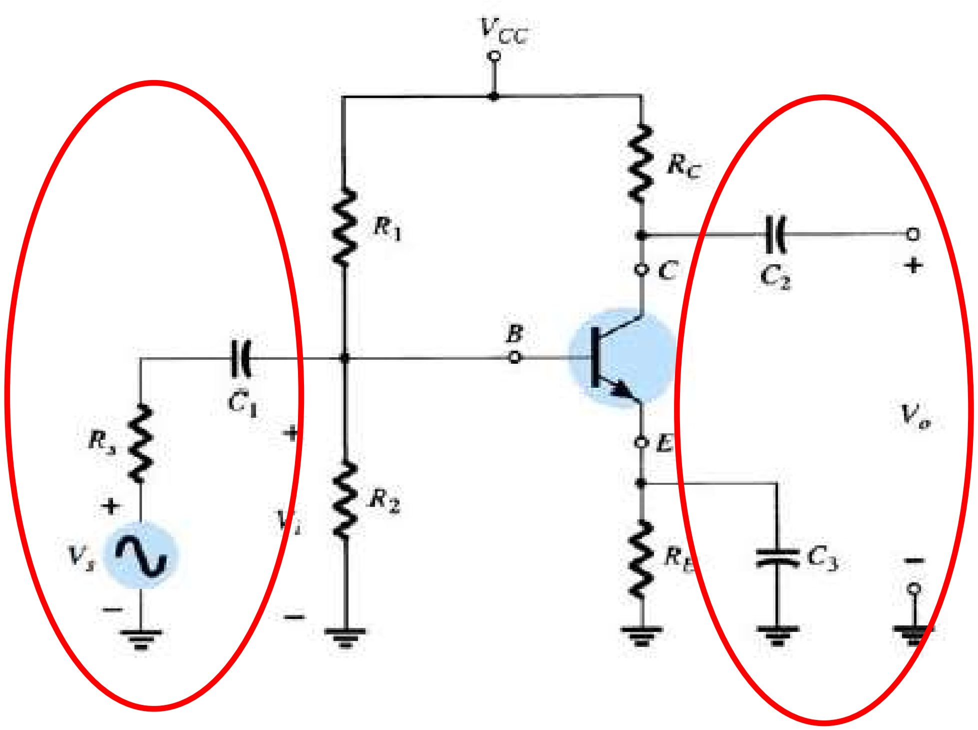
Mạch định thiên kiểu phân áp cho npn-BJT có tụ nhánh C_E

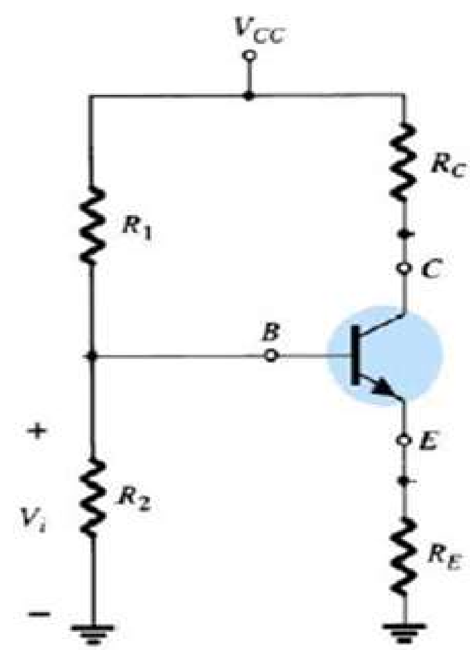
(With Bypass Capacitor C_E)



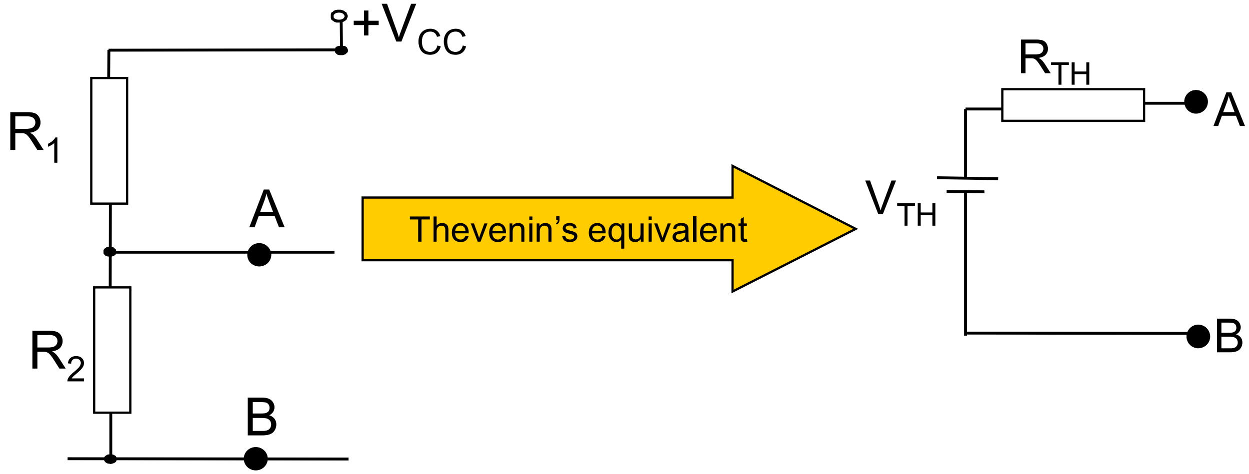
Đặc tính mạch định thiện kiểu phân áp

- Phổ biến hay dùng nhất vì có hskđ áp, dòng hay công suất
  It is the most commonly used biasing circuit because it can have voltage gain, current gain or power gain.
- Ưu điểm
  - → Điểm Q ổn định.
  - → 1 nguồn cấp V_{CC}.
- Nhược điểm
  - → Khá phức tạp





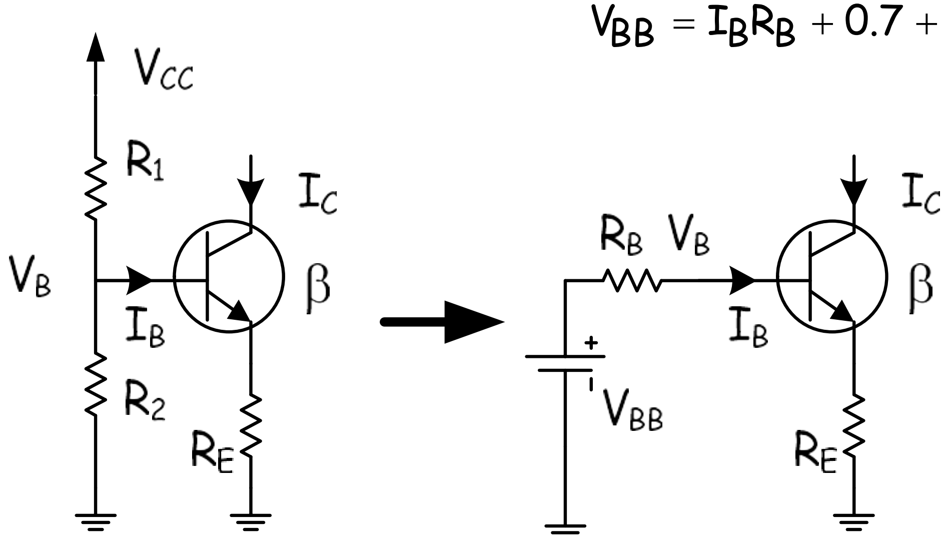
4.2 Phân tích một chiều cho mạch kiểu phân áp (by Thevenin's theorem)



Mạch định thiên DC

$$R_{th} = R_B = R_1 // R_2 = \frac{R_1 R_2}{R_1 + R_2} \quad \text{and} \quad V_{th} = V_{BB} = V_{cc}\frac{R_2}{R_1 + R_2}$$

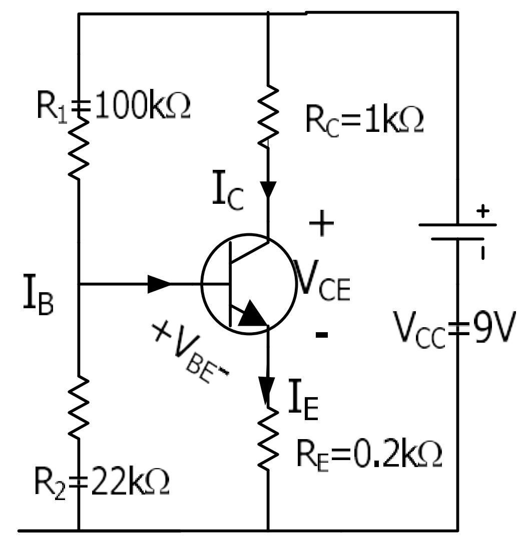
$$V_{BB} = I_B R_B + 0.7 + I_C R_E = \frac{I_C}{\beta} R_B + 0.7 + I_C R_E \Rightarrow I_C = \frac{V_{BB} - 0.7}{\left(R_B/\beta\right) + R_E}$$



4.3 Phân tích mạch định thiên kiểu phân áp

<u>VD:</u>

Cho mạch BJT có V_{CC}=9V, β=50 , R_1=100kΩ , R_2=22kΩ, R_C=1kΩ . R_E=0.2kΩ, V_{BE}=0.7V, tìm I_B, I_C, I_E,V_{CE}, và áp PCN V_{CB}.



$$R_{th} = R_B = \frac{R_1R_2}{R_1 + R_2} = \frac{100k \times 22k}{122k} = 18k \text{ and}$$

$$V_{th} = V_{BB} = V_{cc}\frac{R_2}{R_1 + R_2} = \frac{9 \times 22k}{100k + 22k} = 1.623V$$

$$V_{BB} = I_BR_B + 0.7 + (I_C + I_B)R_E = \frac{I_C}{\beta}R_B + 0.7 + \left(I_C + \frac{I_C}{\beta}\right)R_E$$

$$I_C = \frac{V_{BB} - 0.7}{(1 + 1/\beta)R_E + R_B/\beta} = \frac{1.623 - 0.7}{0.2k + 18k/50} = \underline{\underline{1.648mA}} \Rightarrow \left[\text{taking } 1/\beta << 1\right]$$

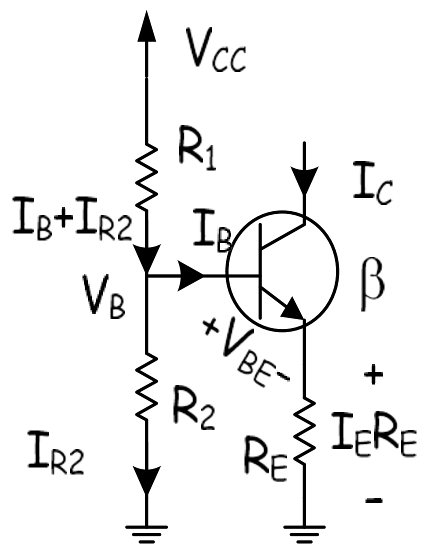
$$I_B = \frac{I_C}{\beta} = \frac{1.648}{50} = \underline{\underline{32.96\mu A}} \Rightarrow I_E = (1.648 + 0.03296)mA = \underline{\underline{1.68mA}}$$

$$V_{CE} = 9 - ((I_C) \times 1k + 0.2k) = 9 - (1.648mA \times 1.2k) = \underline{\underline{7.022V}}$$

$$V_{CE} = V_{CB} + 0.7 \Rightarrow V_{CB} = 7.022 - 0.7 = \underline{\underline{6.322V}}$$

4.4 Phân tích gần đúng mạch định thiên kiểu phân áp (approximate analysis)

Nếu chọn R2 nhỏ so với βR_E và nếu cho phép sai số 10% , nghĩa là $\beta R_E \geq 10R_2$
Khi đó $I_{R2} \geq 10I_B$ hay I_B=nhỏ có thể bỏ qua so với I_{R2} (approximate)

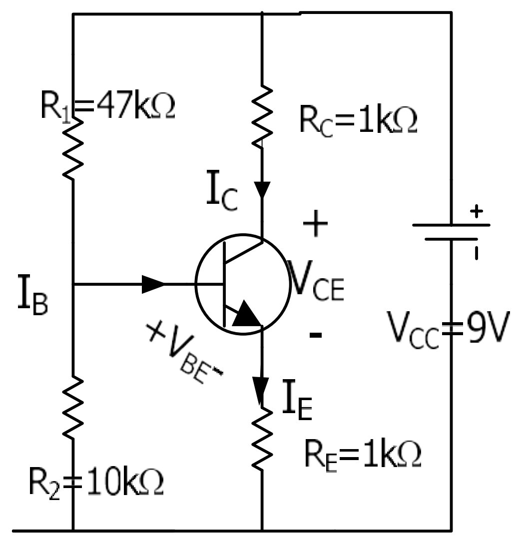


Then we can take $V_{R2} = V_B = V_{CC}\dfrac{R_2}{R_1 + R_2}$

$$= V_{BE} + I_E R_E$$
$$= V_{BE} + I_C R_E \ \left[\text{Approximate again that } I_E = I_C \text{ if } \beta >> 1\right]$$

VD:

Sử dụng PP tính toán gần đúng, phân tích mạch BJT dưới với V_{CC}=9V, β=200 , R_1=47kΩ , R_2=10kΩ, R_C=1kΩ . R_E=1kΩ , cho V_{BE}=0.7V, tìm I_B, I_C, I_E,V_{CE}, và V_{CB}.



Check $10R_2 \le \beta R_E \Rightarrow 100k \le 200 \times 1k = 200k$ OK for approximate method

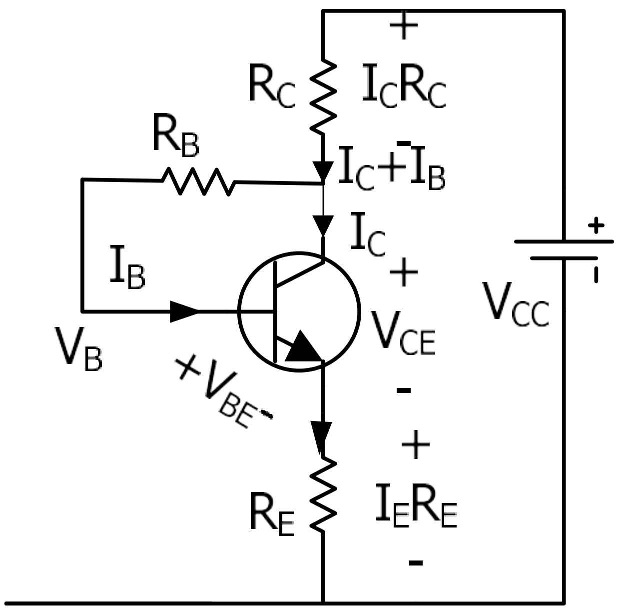
$$V_{CC}\frac{R_2}{R_1+R_2} = V_{BE} + I_C R_E = 9\frac{10k}{57k} = 0.7 + I_C \times 1k$$

$$I_C = \frac{0.879}{1k} = \underline{\underline{0.879mA}} \Rightarrow I_B = \frac{0.879}{200} = \underline{\underline{4.39\mu A}} \Rightarrow I_E = 0.879 + 0.004 = \underline{\underline{0.883mA}}$$

Aproximating $\beta >> 1$, $I_C = I_E$

$$V_{CE} = 9 - I_C \times 2k = \underline{\underline{7.242V}} \Rightarrow V_{CB} = V_{CE} - V_{BE} = 7.242 - 0.7 = \underline{\underline{6.542V}}$$

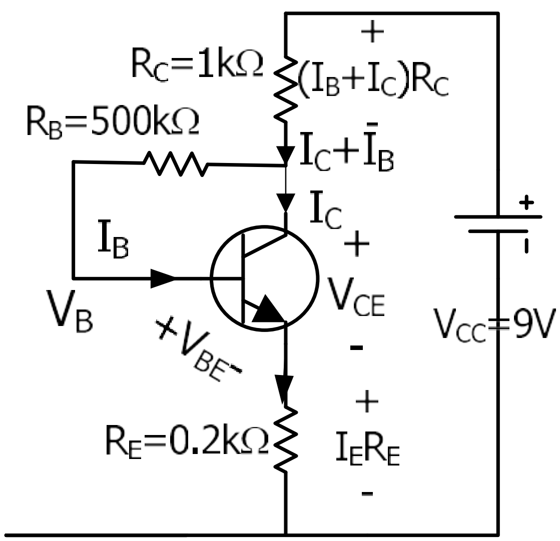
5. BJT Feedback bias circuit



Feedback bias has I_B obtained by R_B from collector voltage for better control on I_C and R_E connected to Emitter for very much better stabilization of I_C

Example:

Following BJT Feedback bias circuit has V_{CC}=9V, β=50 , R_B=500kΩ , R_C=1kΩ . R_E=0.2kΩ If V_{BE}=0.7V, find Base current I_B, Collector current I_C, Emitter current I_E, V_{CE}, and reverse bias voltage V_{CB}.



$$V_{CC} = I_B R_B + 0.7 + (I_C + I_B)(R_E + R_C)$$

$$9 = \frac{I_C}{50}500k + 0.7 + I_C(1 + 0.02)(0.2k + 1k)$$

$$I_C = \frac{9 - 0.7}{1.224k + 500k/50} = \underline{\underline{0.739mA}}$$

$$I_B = \frac{I_C}{\beta} = \frac{739\mu A}{50} = \underline{\underline{14.78\mu A}} \Rightarrow I_E = 739 + 14.78 = \underline{\underline{753.78\mu A}}$$

$$V_{CE} = 9 - ((I_C + I_B) \times 1k + 0.2k) = 9 - (753.78\mu \times 1.2k) = \underline{\underline{8.095V}}$$

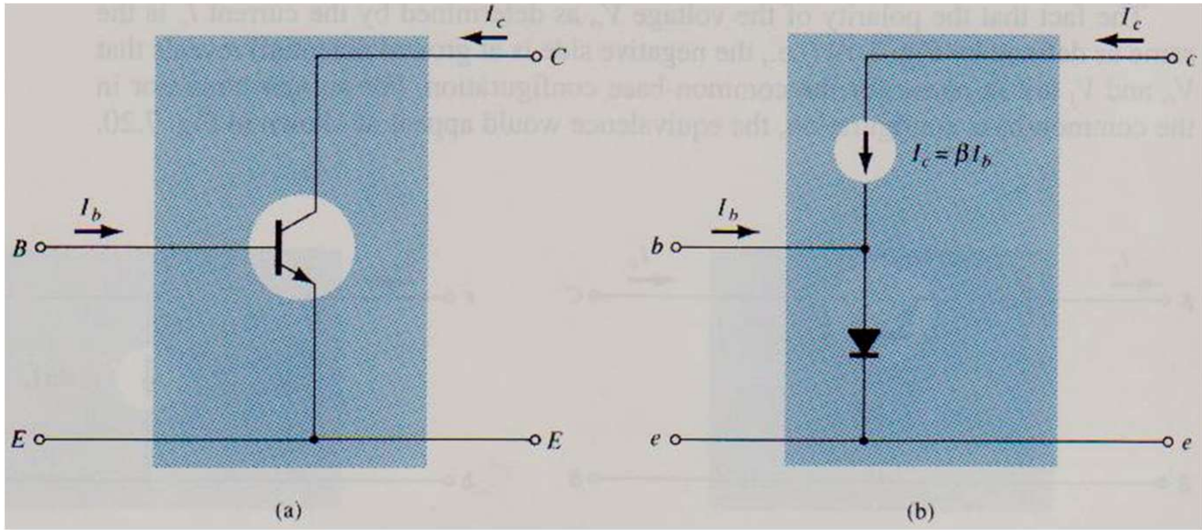
$$V_{CE} = V_{CB} + 0.7 \Rightarrow V_{CB} = 8.096 - 0.7 = \underline{\underline{7.395V}}$$

Phân tích tín hiệu nhỏ cho BJT

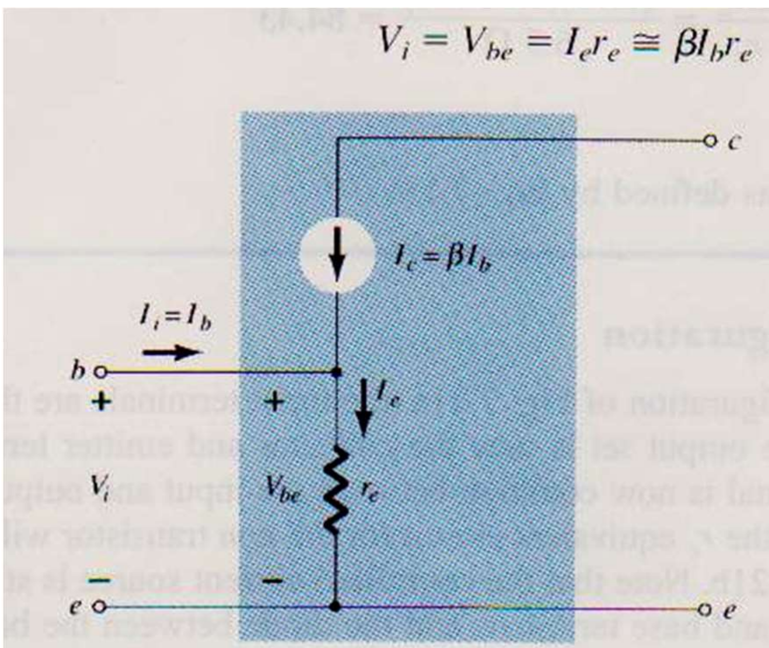
(Small Signal Analysis)

- Drawing Equivalent circuit
- Analysis of Fixed bias amplifier
- Analysis of Emitter bias amplifier
- Analysis of Voltage divider bias amplifier
- Analysis of Feedback bias amplifier
- Analysis of Emitter Follower amplifier
- Analysis of Common Base amplifier

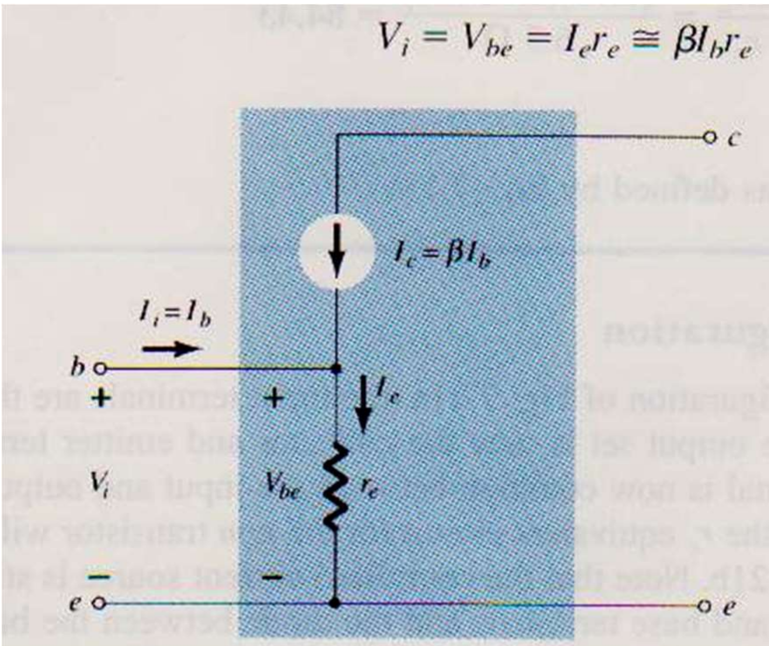
Mô hình BJT r_e/r_π

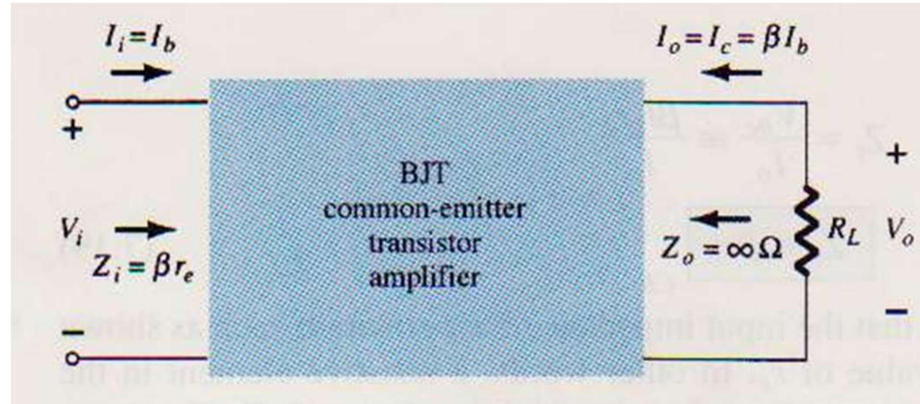


BJT dc Bias current I_b will produce I_c and BE junction behave as a diode

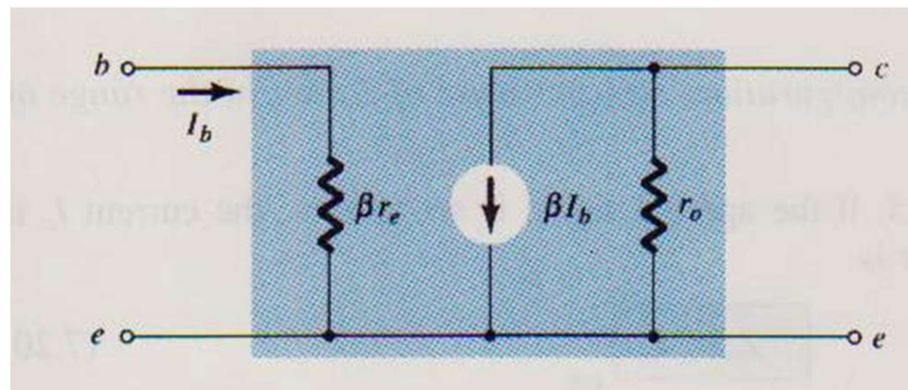


Điện trở động cực B: r_e= 26mV/I_C ($I_C=\beta I_B$)
r_e là điện trở tiếp giáp pn tại cực B, tạo ra điện áp: $V_{be}=(I_b+\beta I_b)r_e \approx I_b\beta r_e$
Do đó trở kháng đầu vào: $V_{be}/ I_b = \beta r_e$





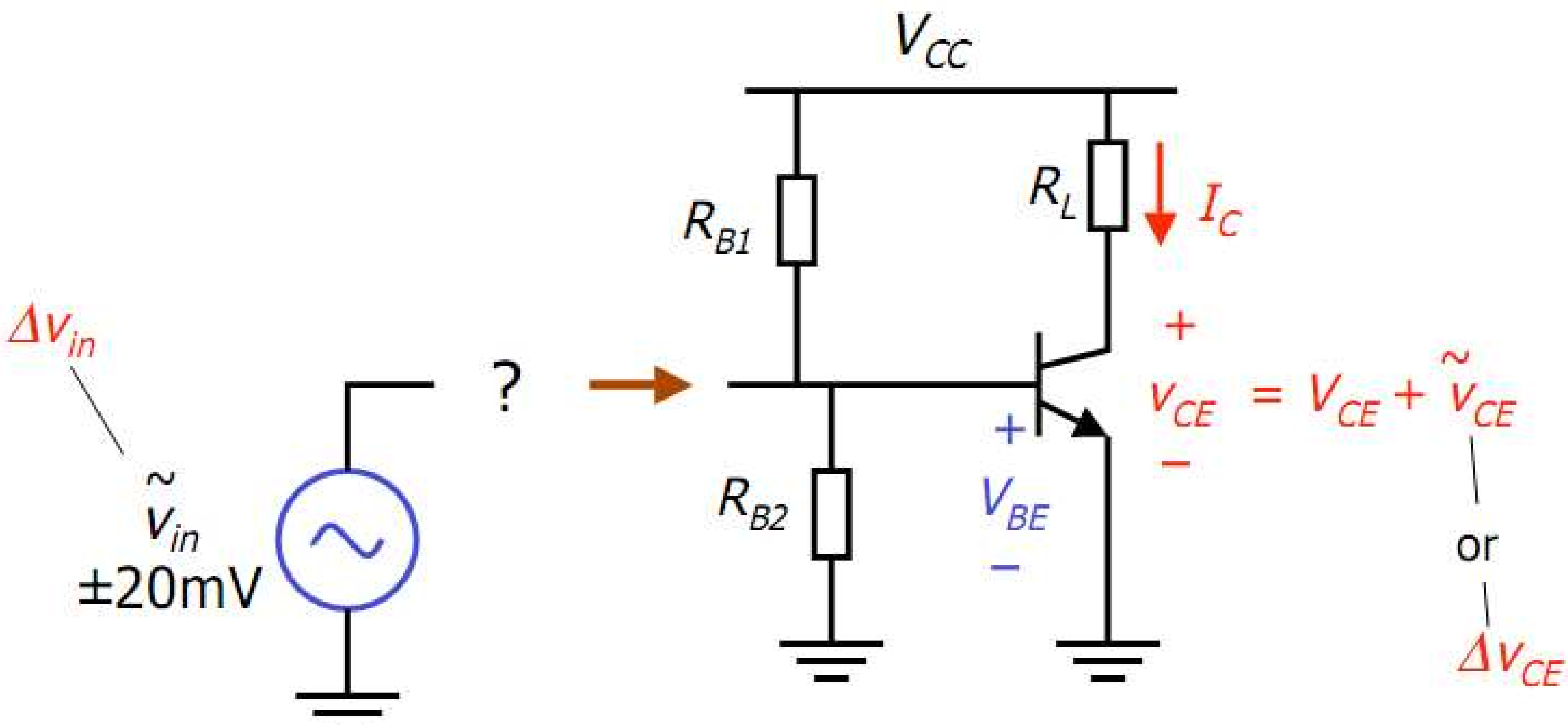
- Trở kháng vào của BJT $R_i = \beta r_e$



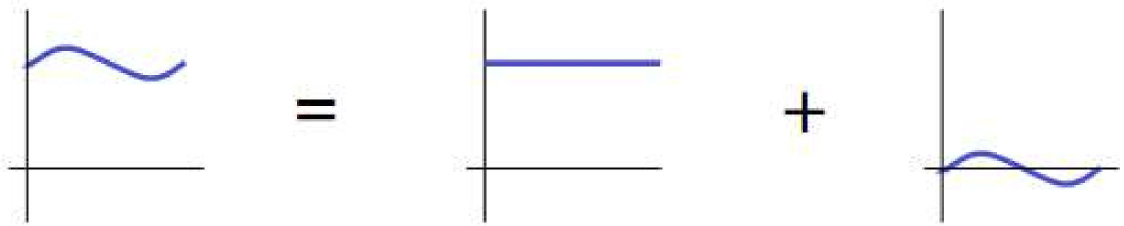
Mô hình BJT r_e

- **Trở kháng ra của BJT: $R_{out} = \infty // r_o = r_o$**
  (điện trở nguồn dòng βI_b là vô cùng)

Đưa tín hiệu (AC nhỏ) vào mạch bằng cách nào?



Ký hiệu về tín hiệu



$$v_{CE} = V_{CE} + \tilde{v}_{CE}$$

total signal
(large signal)

operating point
or
DC value
or
quiescent point

small signal
or
ac signal

Total signal
a

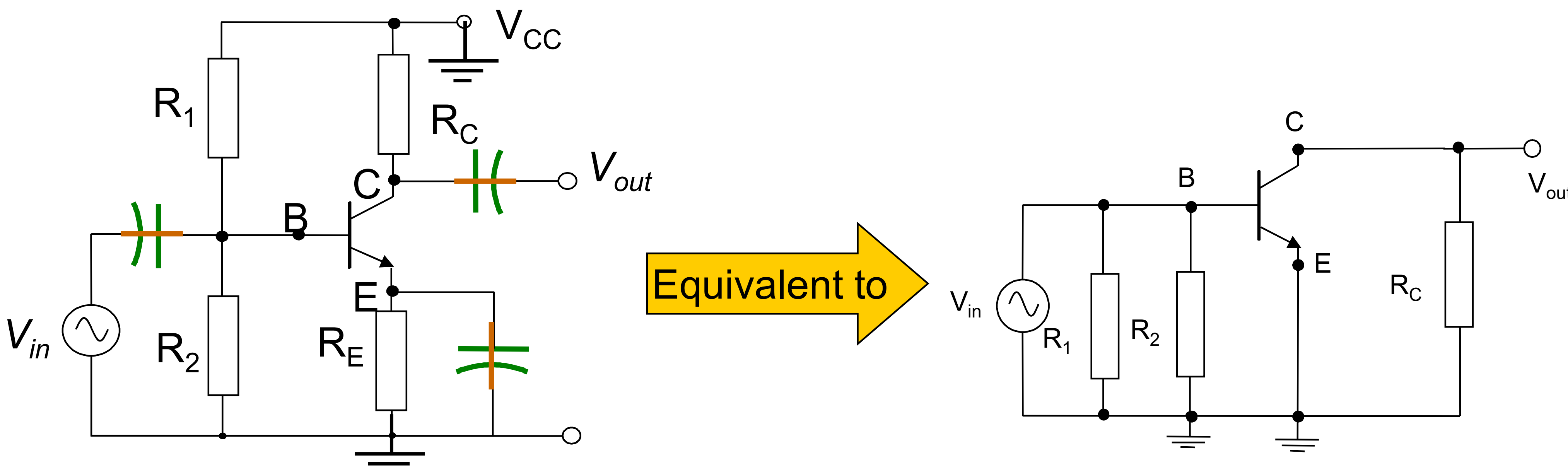
DC point
A

Small signal

$\tilde{a}$ or Δa

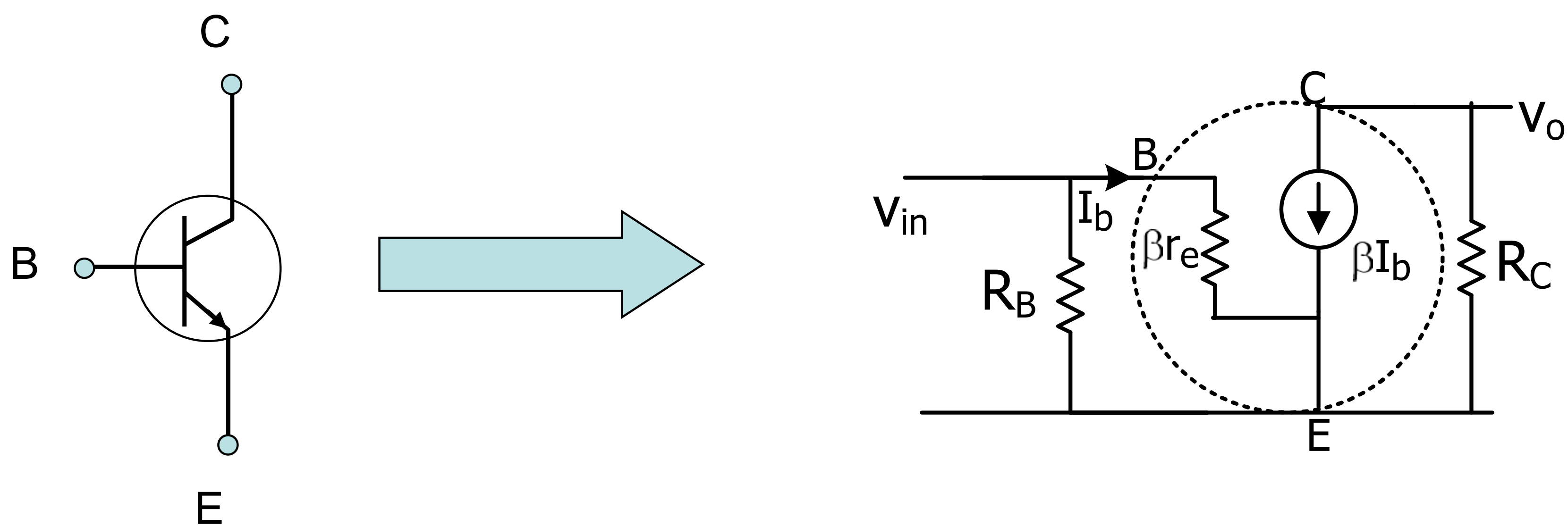
Mạch AC tương đương

- **Để chuyển mạch KĐ sang mạch xoay chiều AC tương đương thì cần:**
  To transform the amplifier circuit to its ac equivalent circuit, the following procedures should be followed.
  1. **Ngắn mạch nguồn DC (ZERO).**
  2. **Ngắn mạch tụ.**
  3. **Hỏ mạch cuộn dây.**
  4. **Vẽ lại mạch.**

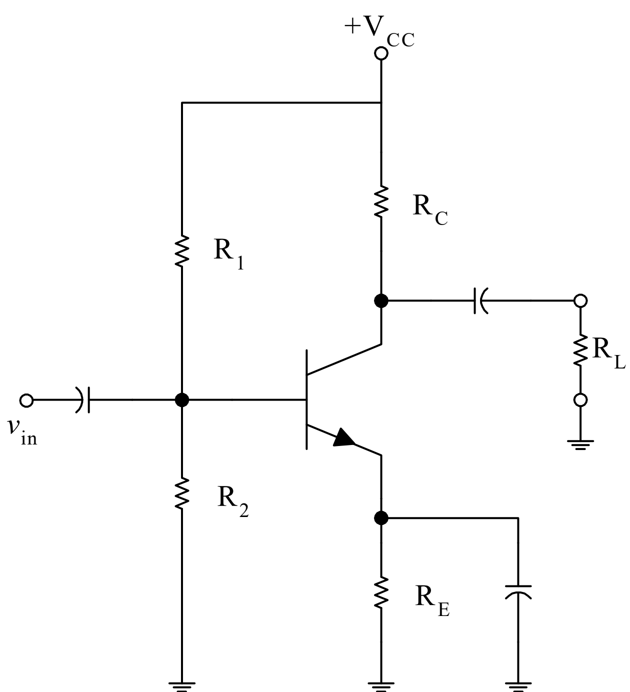


Mạch AC tương đương

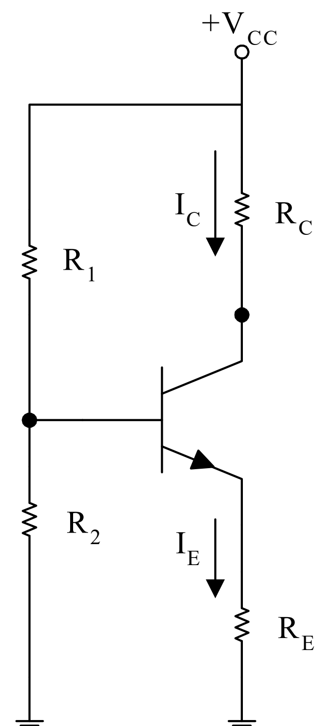
- **In order to better visualise the operation of a transistor in an amplifier circuit, it is often useful to represent the BJT by an equivalent circuit.**
- **An equivalent circuit uses various internal transistor parameters (usually specified by the manufacturer of the BJT) to represent the BJT's operation.**
- **We would limit ourselves to one type of BJT's model:**
  - *The Norton Equivalent of Eber Moll's model*



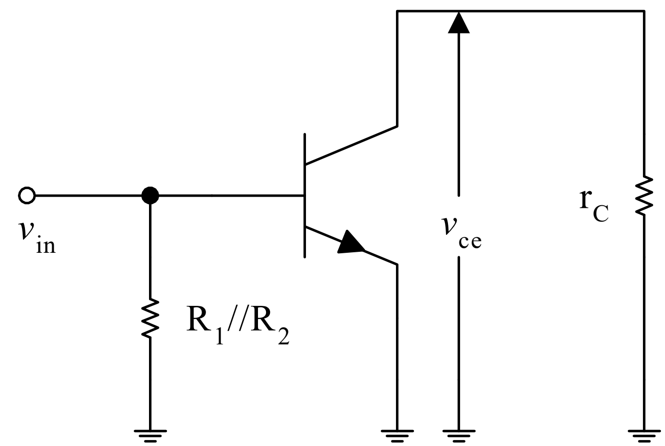
Mạch AC và DC tương đương



Mạch định thiên



Mạch DC tương đương



$r_C = R_C // R_L$

Mạch AC tương đương

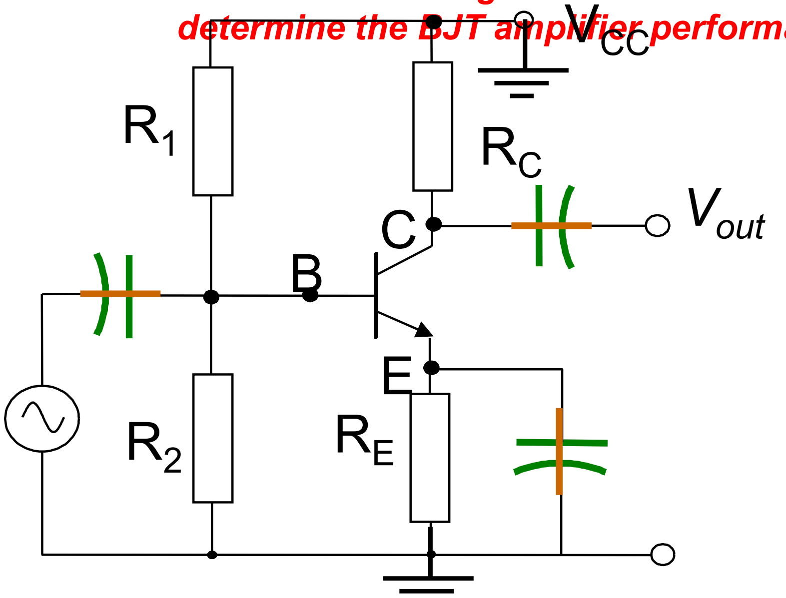
Phân tích AC của mạch KĐ tín hiệu lớn?
AC Analysis of a Large-Signal Transistor Amplifier

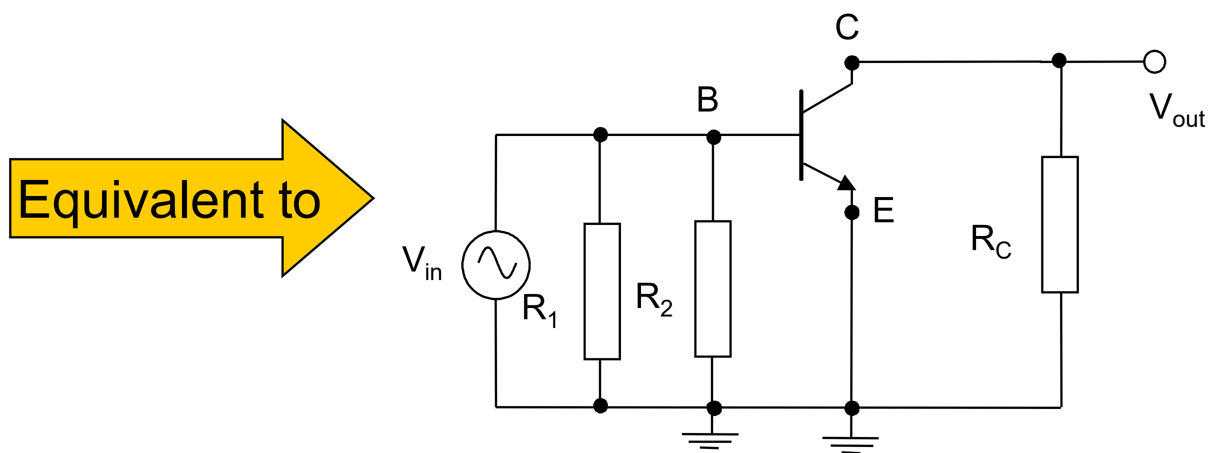
- Khi điện áp đỉnh-đỉnh của tín hiệu xoay chiều của dòng IE < 10% dòng điện tĩnh DC cực E thì sử dùng được sơ đồ tương đương AC tín hiệu nhỏ

  When the small-signal peak-peak ac emitter current is **less than 10% of the dc quiescent emitter current**, the Eber Moll's equivalent circuit can be used.

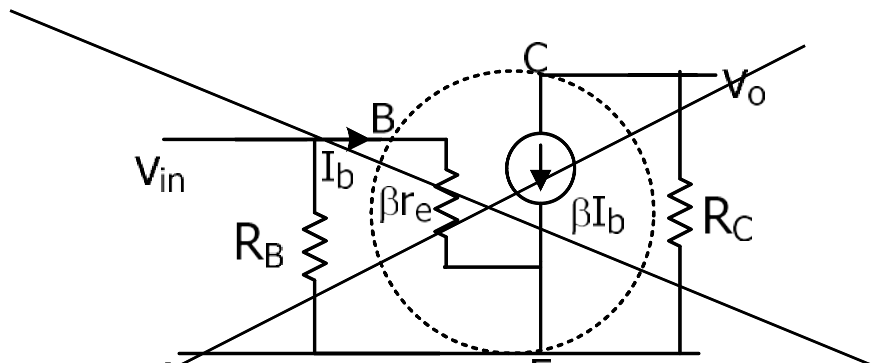
- ***Khi t/h nhỏ > 10%, sử dụng sơ đồ t/h lớn để phân tích BJT. T/h ra có thể bị méo***

  When the small-signal does not satisfy the above 10% condition, large-signal analyzes will be used to determine the BJT amplifier performance. The out-put signal could be distorted.





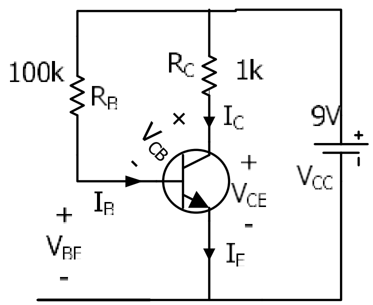
Sơ đồ tương đương AC t/h lớn



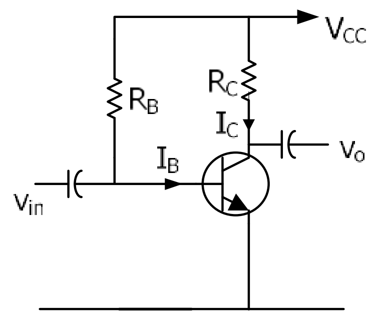
Sơ đồ tương đương t/h nhỏ Eber Moll's

1. Vẽ mạch AC tương đương

1.Cho mạch BJT



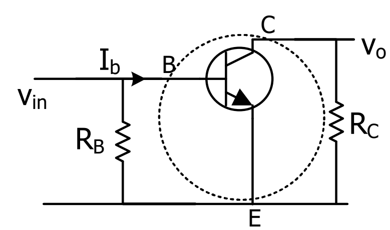
2.KĐ BJT (amplifier)



V_{in} và V_o được nối với KĐ và nguồn pin (battery) được thay bằng V_{CC}

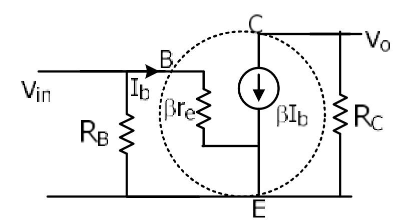
3.Sơ đồ xoay chiều BJT tương đương

Trong sơ đồ AC tương đương, ngắn mạch tụ nối tầng
Nối đất nguồn V_{CC}



4.Mạch tương đương của bộ KĐ

Dùng sơ đồ r_e của BJT

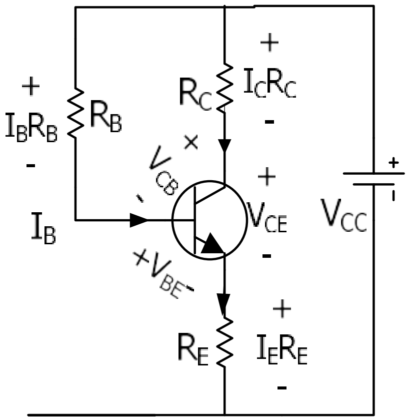


Tìm A_V , R_{in} , R_o , A_I từ sơ đồ tương đương này của bộ KĐ

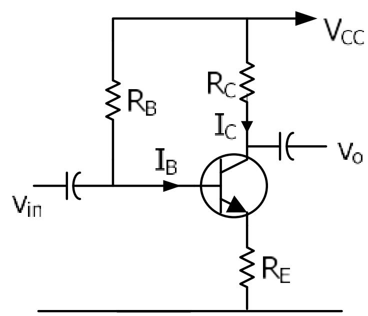
VD:

Vẽ mạch tương đương của bộ KĐ dưới

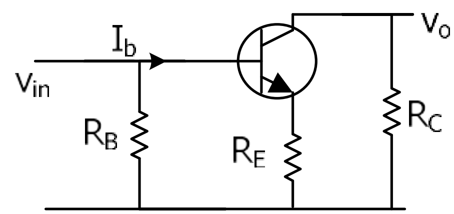
1.Cho mạch BJT dưới



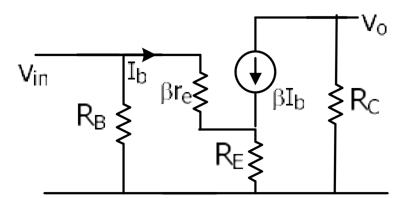
2.KĐ BJT



3.Mạch xoay chiều BJT tương đương



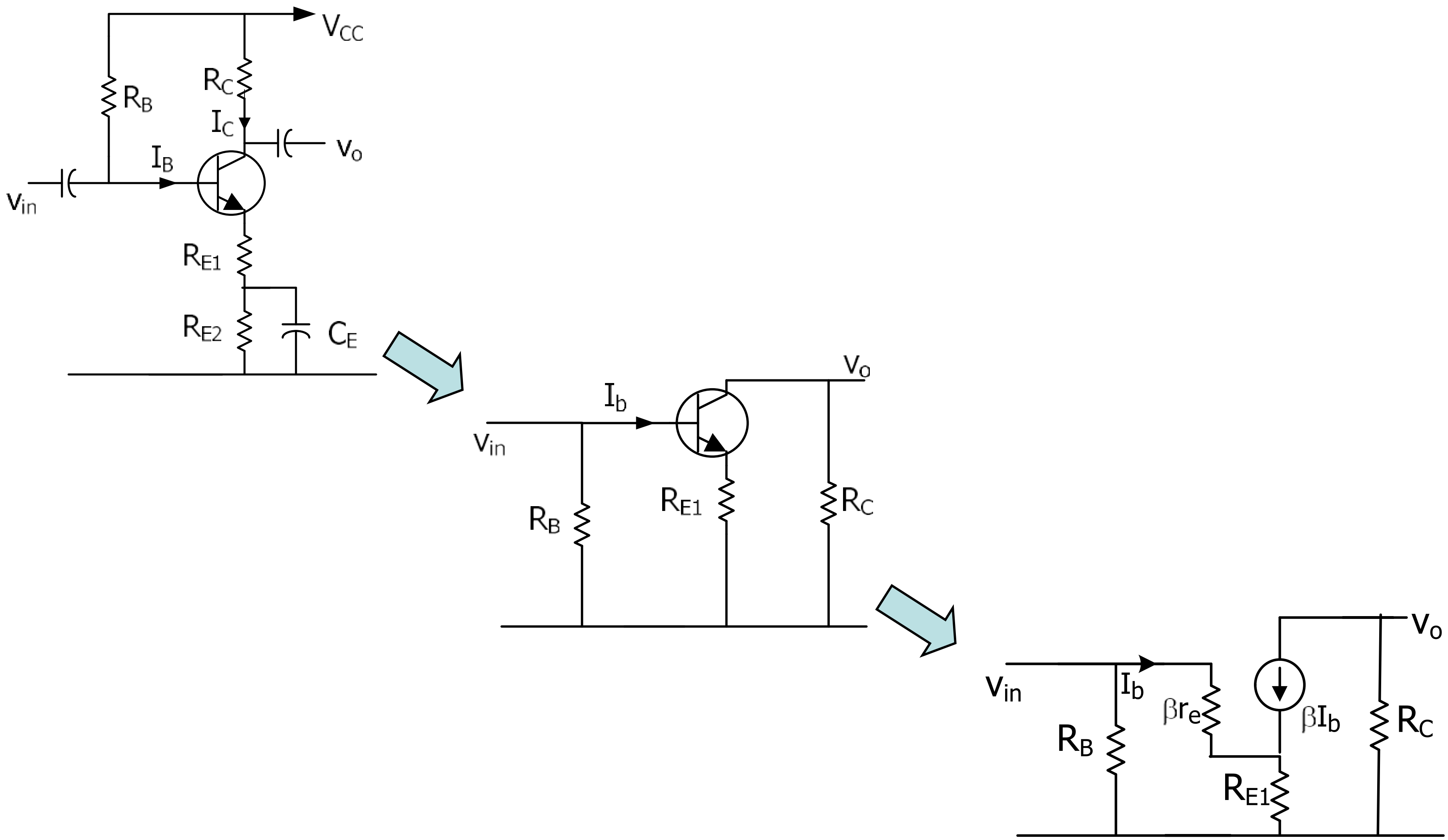
4.Mạch tương đương của bộ KĐ



Tìm A_V , R_{in} , R_o , A_I

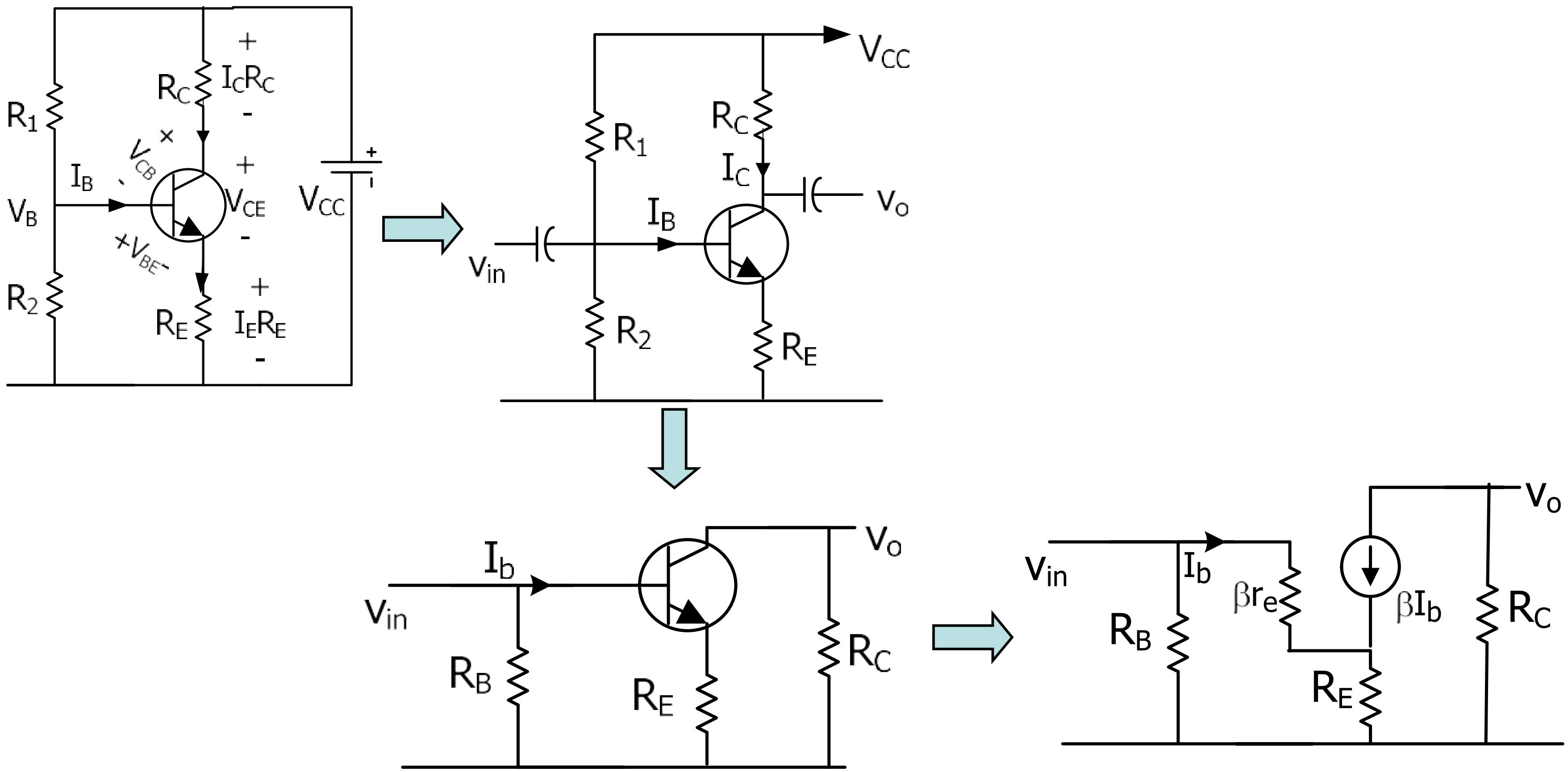
VD:

Vẽ mạch tương đương của bộ KĐ dưới.



VD:

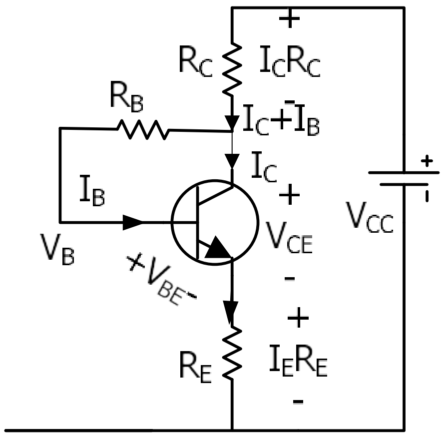
Vẽ mạch tương đương của bộ KĐ dưới.

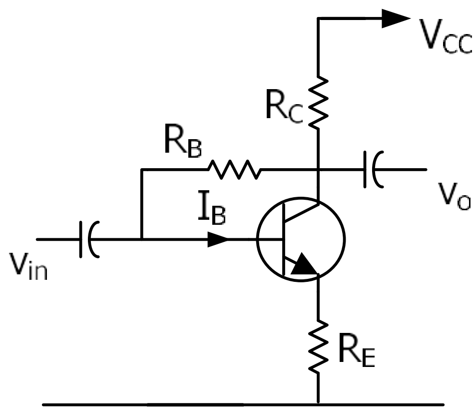


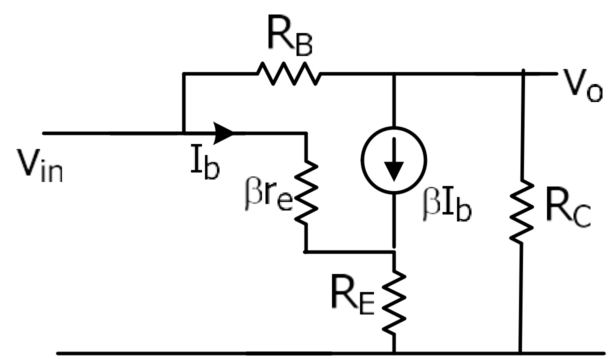
$R_1 // R_2 = R_B$

<u>VD:</u>

Vẽ mạch tương đương của bộ KĐ dưới.





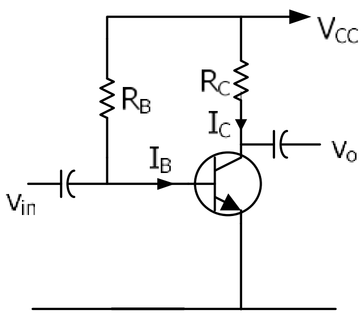


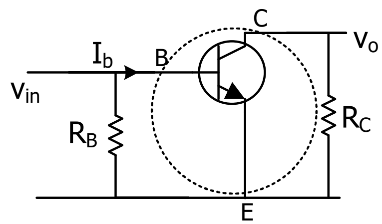
2.Phân tích bộ KĐ định thiên cố định
(Fixed Bias Amplifier)

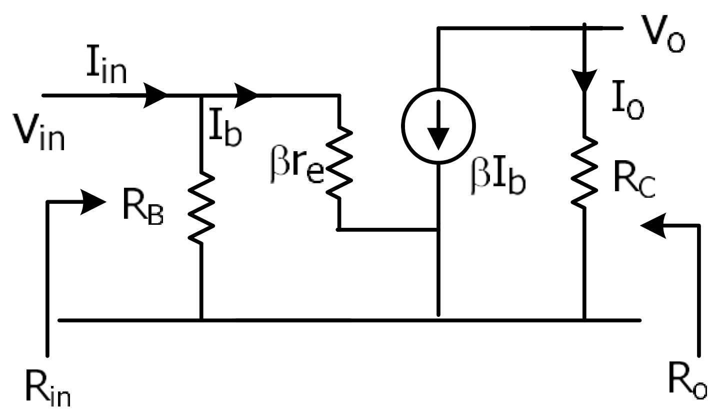
Dùng phân tích t/h nhỏ để tìm A_V , R_{in} , R_o , A_I từ mạch tương đương của bộ KĐ

VD:

Tìm A_V , R_{in} , R_o , A_I sơ đồ KĐ định thiên cố định hình dưới







Note that I_B in dc circuit is changed to ac I_b in ac equivalent circuit. I_B is the dc current due to BJT biasing and I_b is the ac current when V_{in} is present.

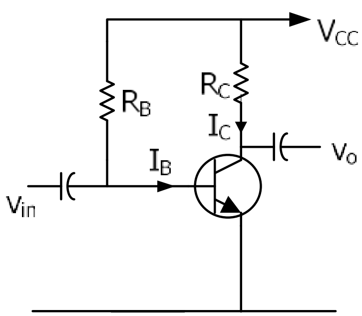
$$R_{in} = R_B // \beta r_e \qquad R_o = R_C // \infty = R_C$$

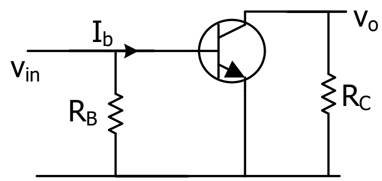
$$A_V = \frac{V_o}{V_{in}} = \frac{(-\beta I_b)R_C}{I_b \times \beta r_e} = -\frac{R_C}{r_e}$$

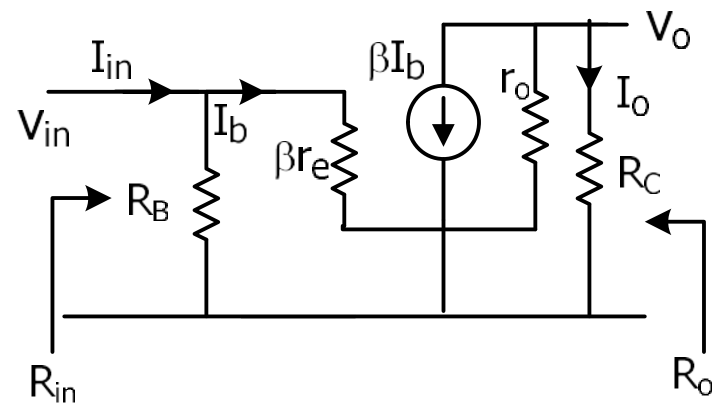
$$A_I = \frac{I_o}{I_{in}} = \frac{V_o / R_C}{V_{in} / R_{in}} = A_V \frac{R_{in}}{R_C} = \left(-\frac{R_C}{r_e}\right)\frac{R_B // \beta r_e}{R_C} = -\frac{R_B // \beta r_e}{r_e}$$

VD:

Tìm A_V , R_{in} , R_o , A_I sơ đồ dưới (có tính đến r_o)







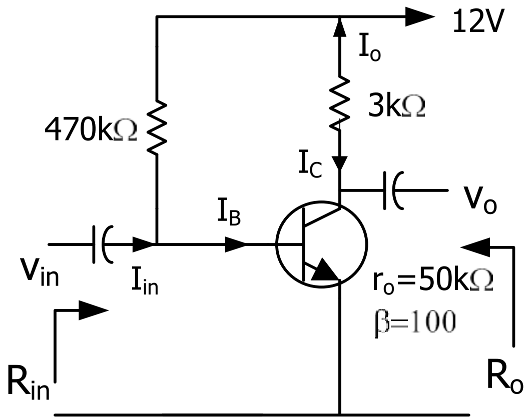
$$R_{in} = R_B // \beta r_e \qquad R_o = R_C // r_o$$

$$A_V = \frac{V_o}{V_{in}} = \frac{(-\beta I_b)(R_C // r_o)}{I_b \times \beta r_e} = -\frac{R_C // r_o}{r_e}$$

$$A_I = \frac{I_o}{I_{in}} = \frac{V_o / R_C}{V_{in} / R_{in}} = A_V \frac{R_{in}}{R_C} = \left(-\frac{R_C // r_o}{r_e}\right)\frac{R_B // \beta r_e}{R_C} = -\left(\frac{R_C // r_o}{R_C}\right)\frac{R_B // \beta r_e}{r_e}$$

VD:

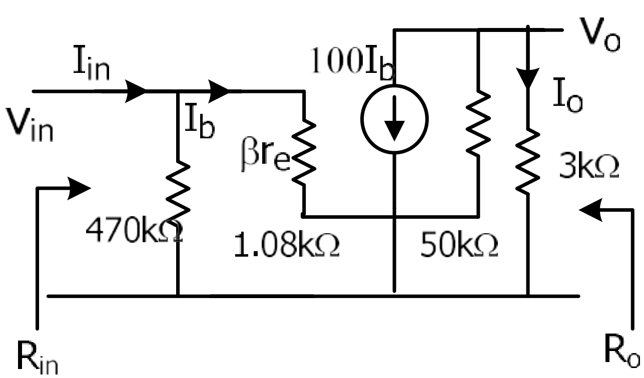
Tìm A_V , R_{in} , R_o , A_I biết r_o=50kΩ



$$12 = I_B \times 470k + 0.7 \Rightarrow I_B = \frac{12-0.7}{470k} = 0.024mA$$

$$I_C = \beta I_B = 100 \times 0.024mA = \underline{\underline{2.4mA}}$$

$$r_e = \frac{26mV}{2.4mA} = \underline{\underline{10.8\Omega}} \Rightarrow \beta re = 100 \times 10.8 = 1080\Omega = \underline{\underline{1.08k\Omega}}$$



$$R_{in} = R_B // \beta r_e = 470k // 1.08k = \underline{\underline{1.078k\Omega}}$$

$$R_o = R_C // r_o = 3k // 50k = \underline{\underline{2.83k\Omega}}$$

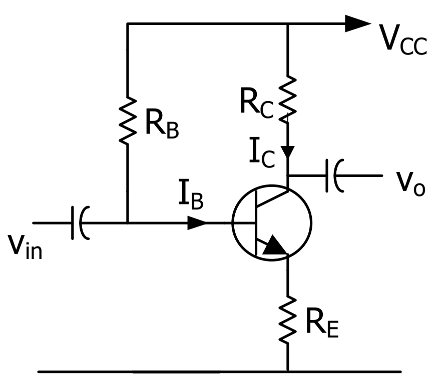
$$A_V = \frac{(-100I_b) \times (3k // 50k)}{I_b \times 1.08k} = -\frac{283k}{1.08k} = \underline{\underline{-262}}$$

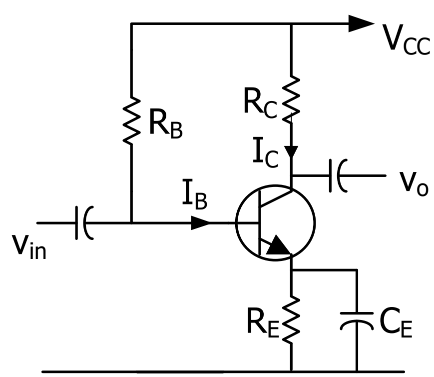
$$A_I = \frac{I_o}{I_{in}} = \frac{V_o / R_C}{V_{in} / R_{in}} = A_V \frac{R_{in}}{R_C} = -262 \frac{1.08k}{3k} = \underline{\underline{-94.33}}$$

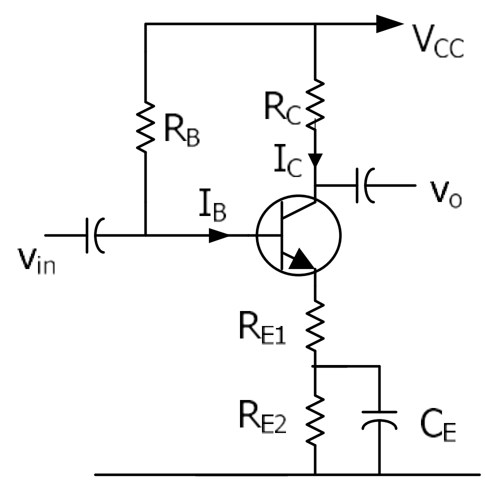
3. Phân tích bộ KĐ định thiên cực E
(Emitter Bias Amplifier)

Connecting R_E at the Emitter of the BJT will have different dc conditions and also different ac parameters compared to Fixed bias amplifier. R_E is very important to stabilize dc currents in BJT and will also stabilize ac parameter A_V (voltage gain of the amplifier).

<u>Xem xét 3 sơ đồ dưới đây</u>







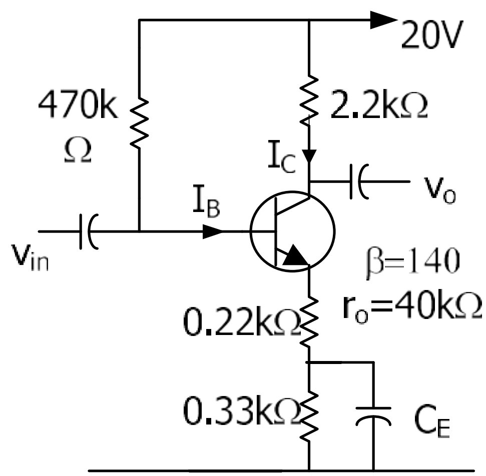
Một điện trở R_E được sử dụng cho cả tính toán DC và AC

R_E được sử dụng để phân tích DC vì C_E bị ngắn mạch trong mạch tương đương AC.

Cả R_{E1} và R_{E2} được sử dụng trong phân tích DC, nhưng chỉ R_{E1} được sử dụng cho phân tích AC (C_E bị ngắn mạch khi đó).

VD:

Tìm A_V , R_{in} , R_o , A_I (bỏ qua r_o)

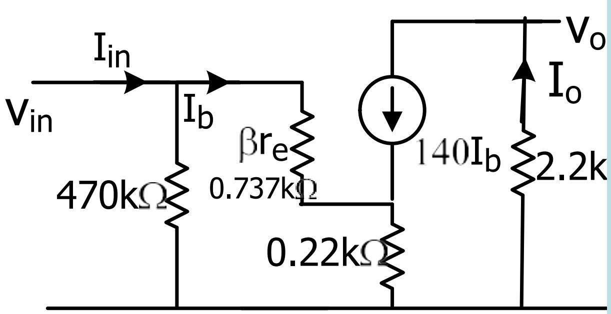


$$20 = I_B \times 470k + 0.7 + \beta I_B \times (0.22k + 0.33k)$$

$$I_B = \frac{12 - 0.7}{470k + (140 \times 0.55k)} = 0.035mA$$

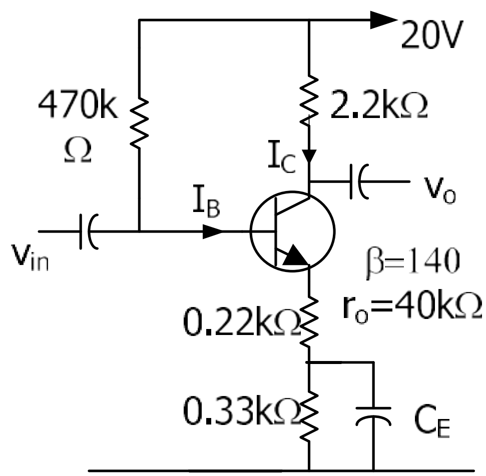
$$I_C = \beta I_B = 140 \times 0.035mA = \underline{\underline{4.94mA}}$$

$$r_e = \frac{26mV}{4.94mA} = \underline{\underline{5.26\Omega}} \Rightarrow \beta r_e = 140 \times 5.26 = 1080\Omega = \underline{\underline{0.737k\Omega}}$$



VD:

Tìm A_V , R_{in} , R_o , A_I (bỏ qua r_o)



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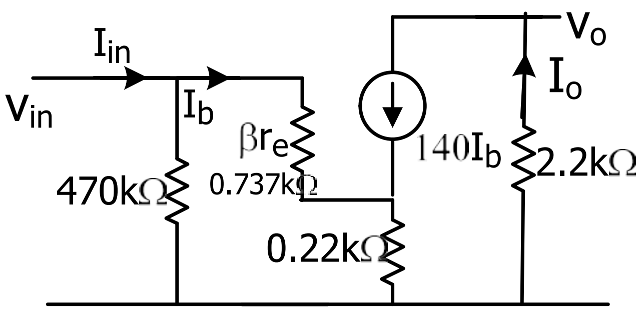


$$V_{in} = I_b \times 0.737k + 140 I_b \times 0.22k \Rightarrow I_b = \frac{V_{in}}{51.537k}$$

$$R_{in} = 470k // (V_{in} / I_b) = 470k // 51.537k = \underline{\underline{48.3k\Omega}}$$

$$R_o = R_C // r_o = R_C = \underline{\underline{2.2k}} \Leftarrow (r_o \text{ neglected})$$

$$A_V = \frac{V_o}{V_{in}} = \frac{(-140 I_b) \times 2.2k}{I_b \times 51.537k} = -\frac{283k}{1.08k} = \underline{\underline{-5.98}}$$

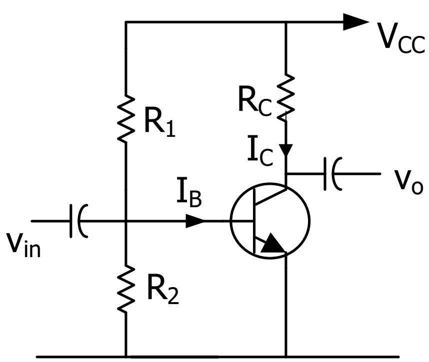
$$A_I = \frac{I_o}{I_{in}} = \frac{V_o / R_C}{V_{in} / R_{in}} = A_V \frac{R_{in}}{R_C} = -5.98 \frac{48.3k}{2.2k} = \underline{\underline{-131.29}}$$

4. Mạch định thiên chia áp

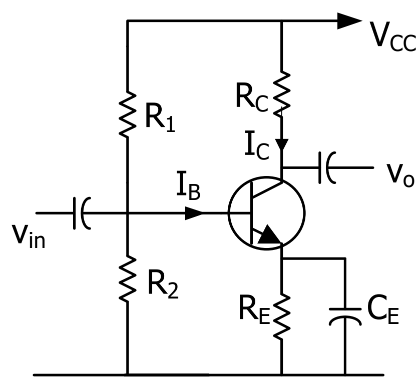
(Voltage divider Bias Amplifier)

Connecting R_1 and R_2 at the Base of the BJT will have more stabilized dc conditions than a single R_B. The input resistance R_{in} becomes lower but voltage gain of the amplifier is not affected.

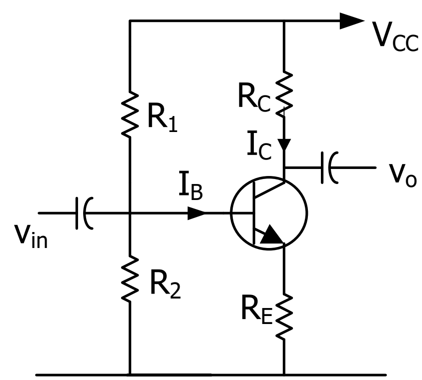
<u>Xem xét 4 sơ đồ</u>



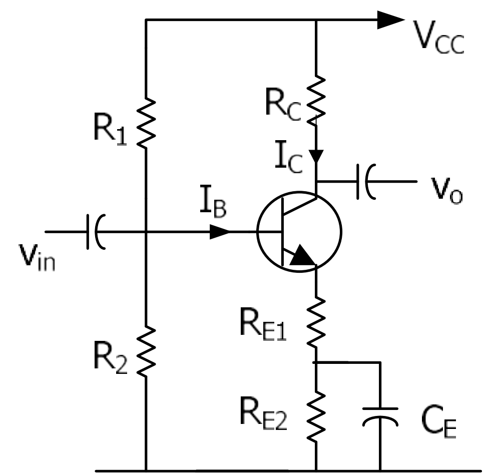
No R_E used for both dc and ac calculations.



Single R_E used for only dc calculations as C_E is short in ac equivalent circuit.



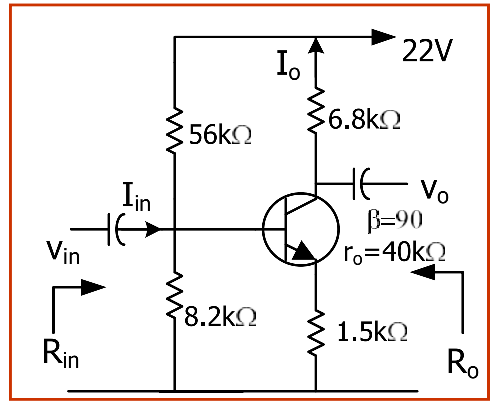
Single R_E used for both dc and ac calculations

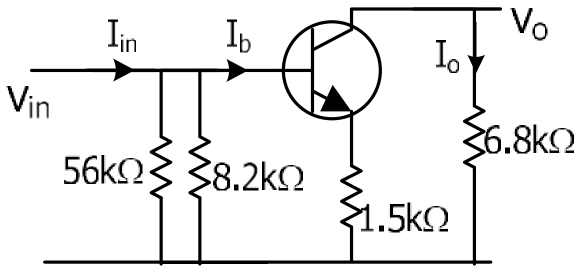


Both R_{E1} and R_{E2} are used for dc calculations and only R_{E1} for ac calculation as C_E is short in ac equivalent circuit.

VD:

Tìm A_V , R_{in} , R_o , A_I (bỏ qua r_o)





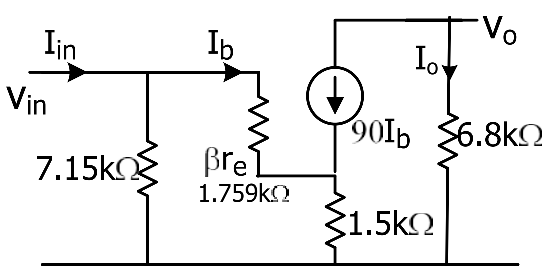
$$V_{BB} = I_B R_B + 0.7 + (I_C + I_B)R_E = \frac{I_C}{\beta} R_B + 0.7 + \left(I_C + \frac{I_C}{\beta}\right) R_E$$

$$I_C = \frac{V_{BB} - 0.7}{(1 + 1/\beta)R_E + R_B/\beta} = \frac{2.8 - 0.7}{1.5k + 7.15k/90} = \underline{\underline{1.33mA}} \Rightarrow \left[\text{taking } 1/\beta << 1\right]$$

$$R_{th} = R_B = \frac{56k \times 8.2k}{64.2k} = 7.15k \text{ and}$$

$$V_{th} = V_{BB} = \frac{22 \times 8.2k}{56k + 8.2k} = 2.8V$$

$$r_e = \frac{26mV}{I_C} = \frac{26mV}{1.33mA} = \underline{\underline{19.55\Omega}} \Rightarrow \beta r_e = 90 \times 19.55 = \underline{\underline{1.759k\Omega}}$$



$R_1//R_2$ = R_B

$$V_{in} = I_b \times 1.759k + 90I_b \times 1.5k \Rightarrow I_b = \frac{V_{in}}{136.76k}$$

$$R_{in} = 7.15k//(V_{in}/I_b) = 7.15k//136.76k = \underline{\underline{6.79k\Omega}}$$

$$R_o = R_C // r_o = R_C = \underline{\underline{6.8k}} \Leftarrow (r_o \text{ neglected})$$

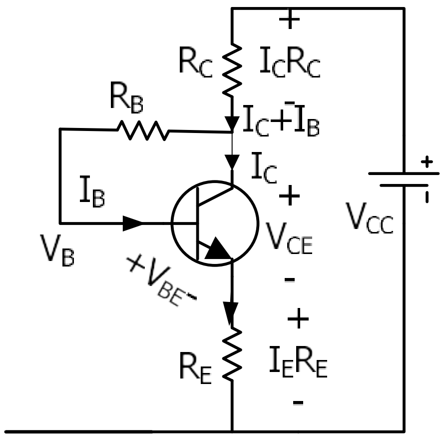
$$A_V = \frac{V_o}{V_{in}} = \frac{(-90I_b) \times 6.8k}{I_b \times 136.76k} = \underline{\underline{-4.475}}$$

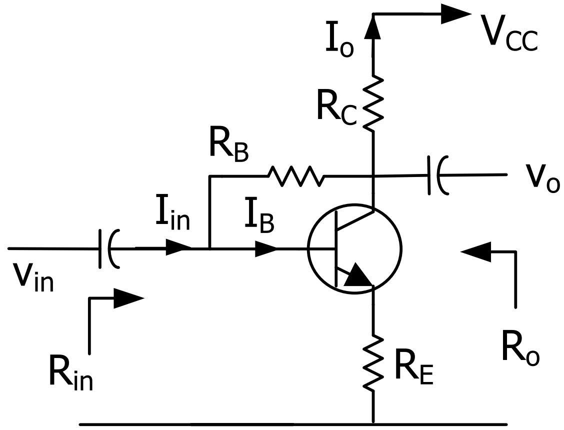
$$A_I = \frac{I_o}{I_{in}} = \frac{V_o/R_C}{V_{in}/R_{in}} = A_V \frac{R_{in}}{R_C} = -4.475 \frac{6.79k}{6.8k} = \underline{\underline{-4.47}}$$

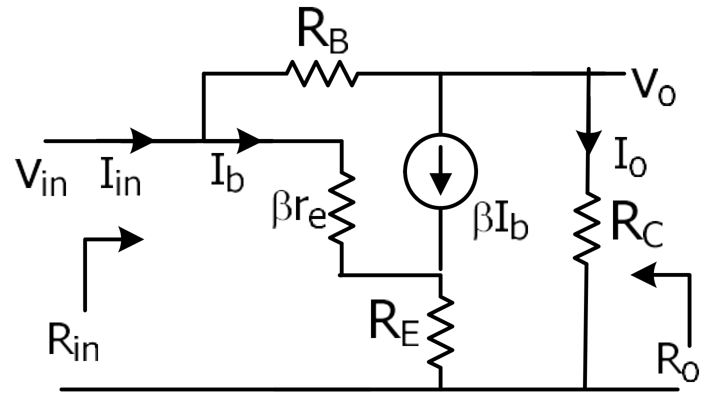
5. Phân tích phân áp phản hồi

(Feedback Bias Amplifier)

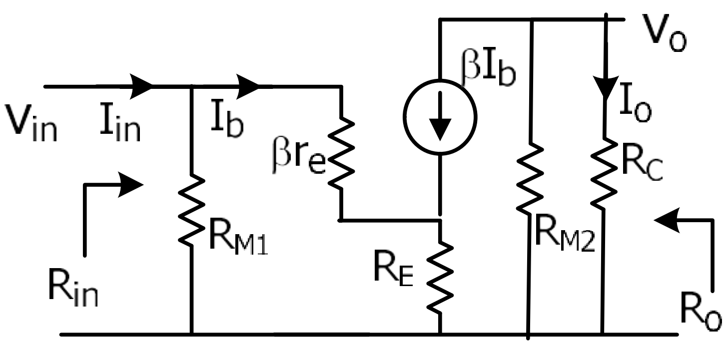
Feedback from Collector to Base by R_B creates a low input resistance R_{in} but a very good dc and ac stabilization is an important part of this amplifier.





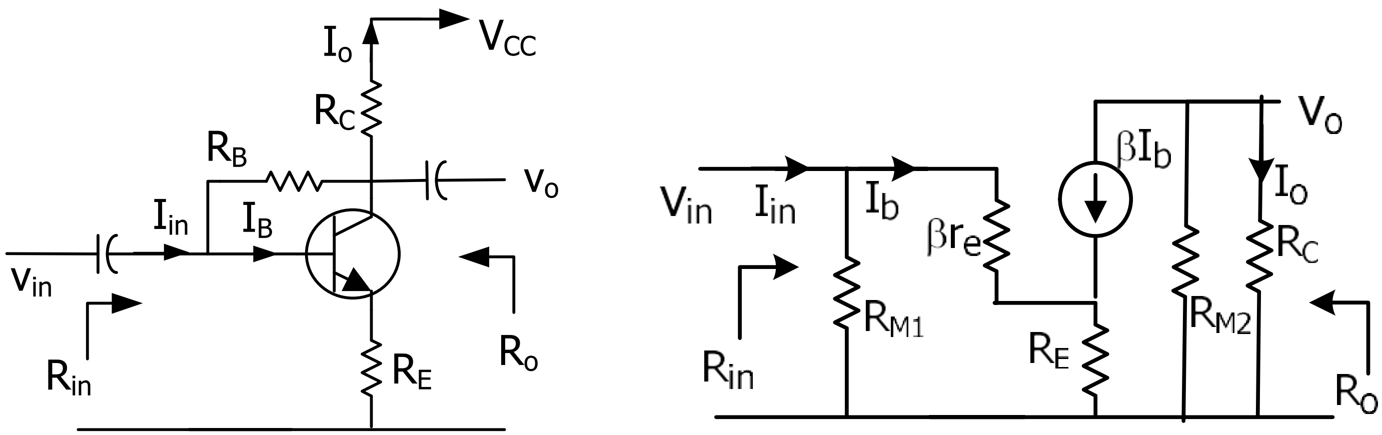


We can apply Miller's theorem to R_B to find R_{in} and also R_o amplifier.



$$A_V = \frac{V_o}{V_{in}} = \frac{-\beta I_b \times R_C}{(I_b \times \beta r_e) + (\beta I_b \times R_E)} = -\frac{\beta R_C}{\beta(r_e + R_E)} = -\frac{R_C}{(r_e + R_E)}$$

$$R_{M1} = \frac{R_B}{1 + \dfrac{R_C}{r_e + R_E}} \approx \frac{R_B}{1 + \dfrac{R_C}{R_E}} \qquad R_{M2} = \frac{R_B}{1 - \dfrac{1}{A_V}} = \frac{R_B}{1 + \dfrac{R_C}{R_E}}$$



$$R_{in} = R_{M1} // \frac{(I_b \times \beta r_e) + (\beta I_b \times R_E)}{I_b} = \frac{R_B}{1 + \frac{R_C}{R_E}} // (\beta r_e + \beta R_E) = \frac{R_B}{1 + \frac{R_C}{R_E}} // (R_E)$$

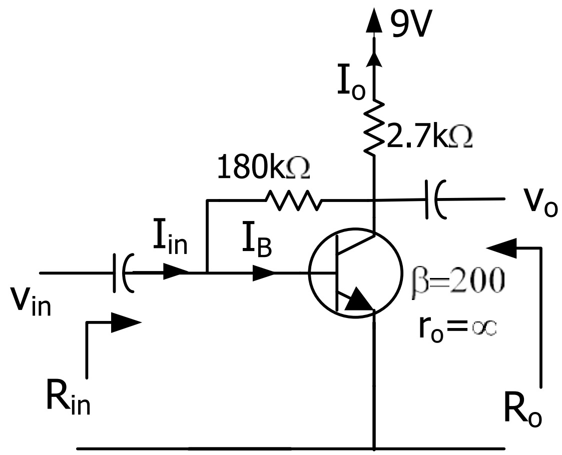
$$R_o = R_C // R_{M2} = R_C // \frac{R_B}{1 - \frac{1}{A_V}} = R_C // \frac{R_B}{1 + \frac{R_C}{R_E}}$$

$$A_V = \frac{V_o}{V_{in}} = \frac{-\beta I_b \times R_C}{(I_b \times \beta r_e) + (\beta I_b \times R_E)} = -\frac{\beta R_C}{\beta(r_e + R_E)} = -\frac{R_C}{(r_e + R_E)}$$

$$\boxed{A_I = \frac{I_o}{I_{in}} = \frac{V_o / R_C}{V_{in} / R_{in}} = A_V \frac{R_{in}}{R_C} = -\left[\frac{R_C}{(r_e + R_E)}\right] \frac{\frac{R_B}{1 + \frac{R_C}{R_E}} // (R_E)}{R_C}}$$

Example:

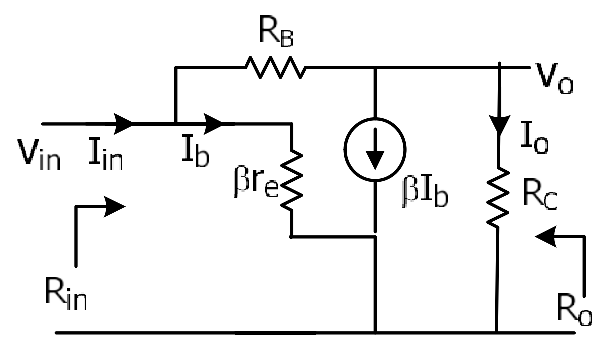
Find the A_V , R_{in} , R_o , A_I of the given Feedback Bias amplifier. Take $I_B << I_C$ and neglect the BJT output resistance r_o



$$9 = \frac{I_C}{200}180k + 0.7 + (I_C)2.7k \Leftarrow (I_B << I_C)$$

$$I_C = \frac{9-0.7}{3.6k} = \underline{\underline{2.3mA}} \Rightarrow r_e = \frac{26mV}{2.3mA} = \underline{\underline{11.3\Omega}}$$

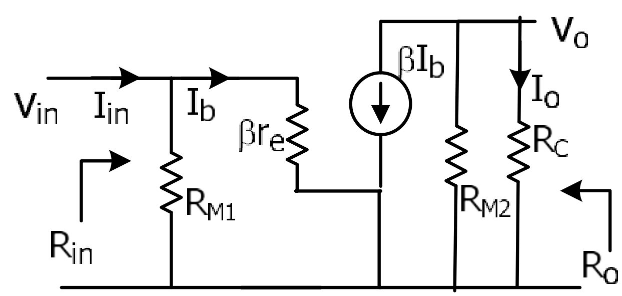
$$A_V = \frac{V_o}{V_{in}} = \frac{-\beta I_b \times R_C}{(I_b \times \beta r_e)} = -\frac{R_C}{(r_e)} = -\frac{2.7k}{11.3\Omega} = \underline{\underline{-238.9}}$$



$$R_{in} = R_{M1} // \beta r_e = \frac{R_B}{1-A_v} = \frac{180k}{1-(-238.9)} // 200 \times 11.3 = \underline{\underline{0.563k\Omega}}$$

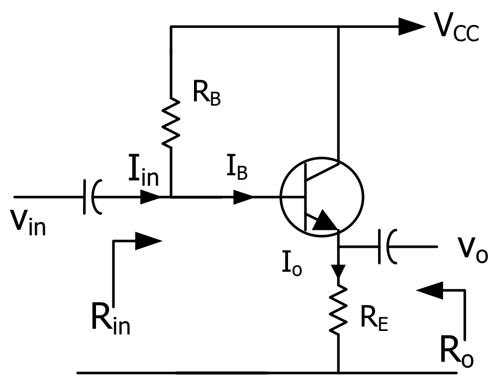
$$R_o = R_{M2} // R_C = \frac{R_B}{1-{}^{1}\!/\!_{A_v}} // 2.7k\Omega = \frac{180k\Omega}{1-{}^{1}\!/\!_{(-238.9)}} // 2.7k\Omega = \underline{\underline{2.66k\Omega}}$$

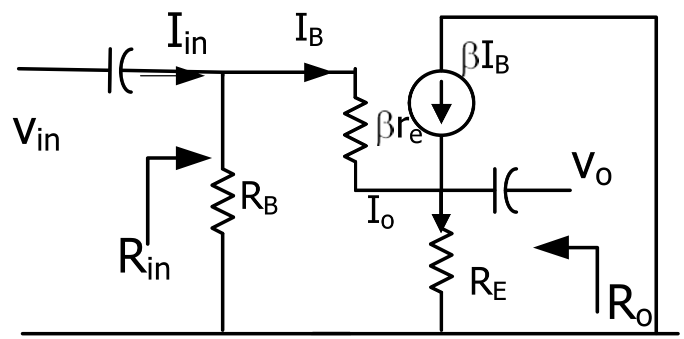
$$A_I = \frac{I_o}{I_{in}} = A_V \frac{R_{in}}{R_C} = -238.9 \frac{0.56k\Omega}{2.7k\Omega} = -\underline{\underline{49.55}}$$



6. Phân tích KĐ bám cực E
(Emitter Follower Amplifier)

Áp ra lấy tại cực E của BJT
(Taking the output voltage at the Emitter instead of Collector of the BJT will create different ac parameters compared to Fixed bias and Emitter bias amplifier especially in <u>voltage gain which will now unity</u>. The <u>output resistance will become very small</u>. Input resistance is the same as Emitter bias amplifier).





$$V_{in} = (I_b \times \beta r_e) + (\beta I_b \times R_E)$$

$$R_{in} = R_B // \frac{V_{in}}{I_b} = R_B // \beta(r_e + R_E)$$

$$A_V = \frac{V_o}{V_{in}} = \frac{\beta I_b \times R_E}{(I_b \times \beta r_e) + (\beta I_b \times R_E)} = \frac{R_E}{r_e + R_E} = 1 \Leftarrow [r_e << R_E]$$

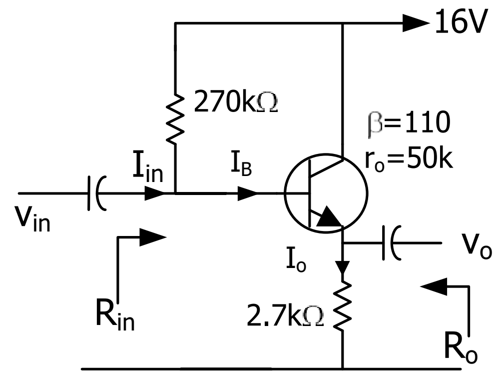
To find $R_o \Rightarrow$ short V_{in} and find $R_o = (V_o / I_o) // R_E$

$$\frac{V_o}{I_o} = \frac{I_b \times \beta r_e}{I_b + \beta I_b} \approx r_e \Rightarrow \therefore R_o = (V_o / I_o) // R_E = r_e // R_E$$

$$A_I = A_V \frac{R_{in}}{R_E} = 1 \times \frac{R_B // \beta(r_e + R_E)}{R_E}$$

VD:

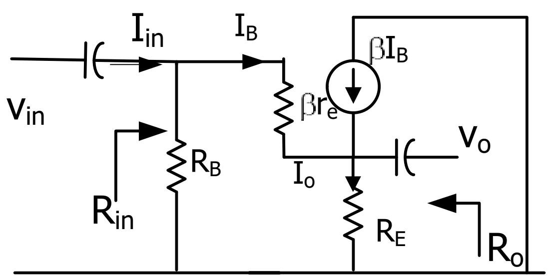
Tìm A_V , R_{in} , R_o , A_I. Lấy $I_B << I_C$ và bỏ qua trở kháng ra r_o



dc analysis

$$16 = \frac{I_C}{110}270k + 0.7 + (I_C)2.7k \Leftarrow (I_B << I_C)$$

$$I_C = \frac{16-0.7}{5.15k} = \underline{\underline{2.97mA}} \Rightarrow r_e = \frac{26mV}{2.97mA} = \underline{\underline{8.75\Omega}}$$



ac analysis

$$V_{in} = (I_b \times \beta r_e) + (\beta I_b \times R_E) \Rightarrow \frac{V_{in}}{I_b} = \beta(r_e + R_E)$$

$$R_{in} = R_B // \frac{V_{in}}{I_b} = 270k//110(8.75+2700) = 270k//298k = \underline{\underline{141.65k\Omega}}$$

$$A_V = \frac{V_o}{V_{in}} = \frac{\beta I_b \times R_E}{(I_b \times \beta r_e) + (\beta I_b \times R_E)} = \frac{R_E}{r_e + R_E} = \frac{2700}{8.75+2700} \approx \underline{\underline{1}}$$

To find $R_o \Rightarrow$ short V_{in} and find $R_o = (V_o / I_o)//R_E$

$$\frac{V_o}{I_o} = \frac{I_b \times \beta r_e}{I_b + \beta I_b} \approx r_e \Rightarrow \therefore R_o = (V_o / I_o)//R_E = r_e // R_E = 8.75//2700 \approx \underline{\underline{8.75\Omega}}$$

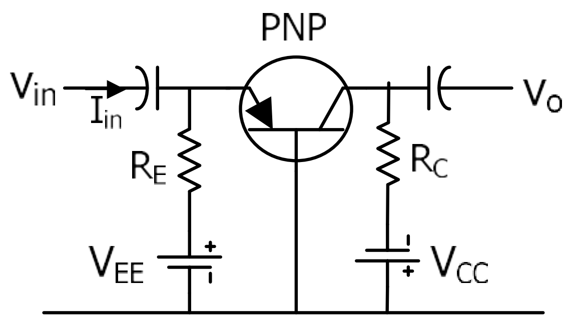
$$A_I = A_V \frac{R_{in}}{R_E} = 1 \times \frac{R_B // \beta(r_e + R_E)}{R_E} = 1 \times \frac{141.65k}{2.7k} = \underline{\underline{52.46}}$$

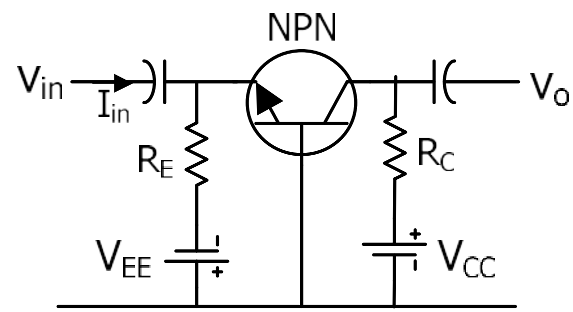
7. Phân tích KĐ B-C

(Common Base Amplifier)

Áp vào đưa vào cực E còn áp ra lấy tại cực C

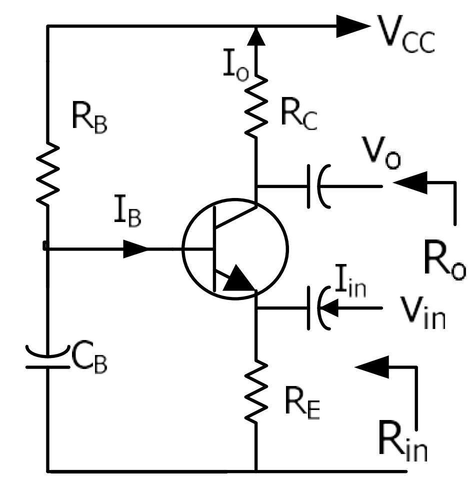
Connecting the input voltage at the Emitter and taking the output voltage at the Collector of the BJT is called Common Base amplifier. It will create the <u>input resistance to become very small</u> The Output resistance is the same as Emitter bias amplifier.

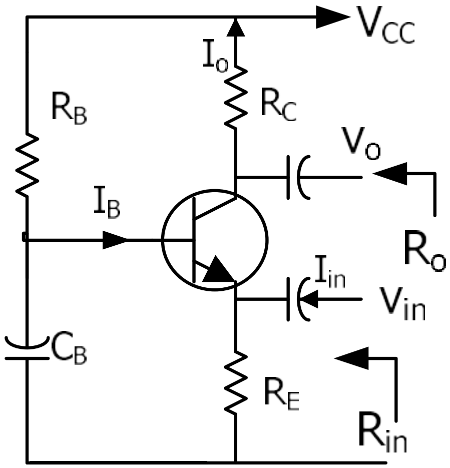




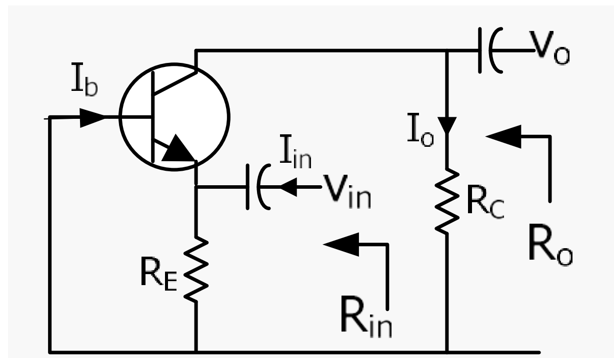
V_{in} nối với cực E còn V_o nối với cực C
Cực B trở thành cực chung cho cả V_{in} và V_o

V_{in} is at the Emitter and V_o is at the Collector
in NPN BJT biased by a single battery Common Base amplifier

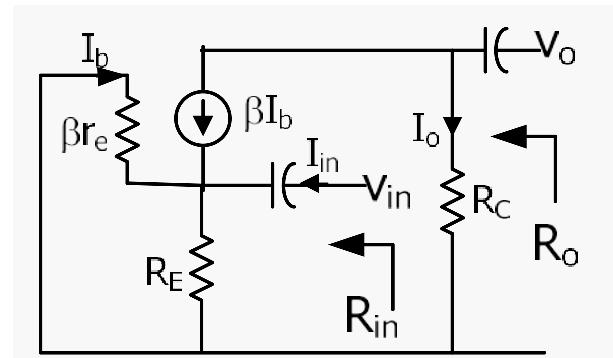




KĐ B-C



Mạch tương đương AC



Mạch tương đương AC của BJT

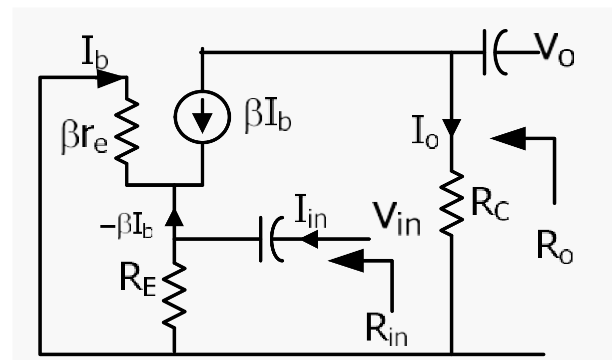
$$R_o = R_C$$

$$R_{in} = R_E // \frac{V_{in}}{-\beta I_b} = R_E // \frac{-I_b \times \beta r_e}{-\beta I_b} = R_E // r_e$$

$$V_{in} = -(I_b \times \beta r_e)$$

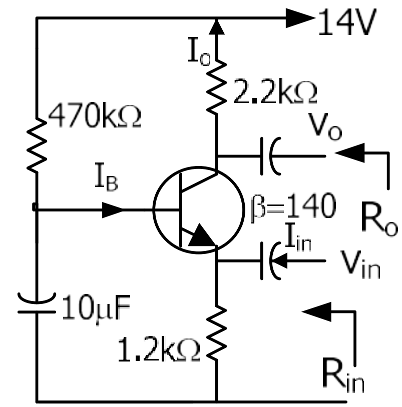
$$A_V = \frac{V_o}{V_{in}} = \frac{-\beta I_b \times R_C}{-(I_b \times \beta r_e)} = \frac{R_C}{r_e}$$

$$A_I = \frac{I_o}{I_{in}} = A_V \frac{R_{in}}{R_C} = \frac{R_C}{r_e} \times \frac{R_E // r_e}{R_C} = \frac{R_E // r_e}{r_e}$$



VD:

Tìm A_V , R_{in} , R_o , A_I. Lấy I_B<<I_C và bỏ qua r_o



$$14 = \frac{I_C}{140}470k + 0.7 + (I_C)1.2k \Leftarrow (I_B << I_C)$$

$$I_C = \frac{14-0.7}{4.56k} = \underline{\underline{2.92mA}} \Rightarrow r_e = \frac{26mV}{2.92mA} = \underline{\underline{8.9\Omega}}$$

$$R_o = R_C = \underline{\underline{2.2k\Omega}}$$

$$R_{in} = R_E // \frac{V_{in}}{-\beta I_b} = R_E // \frac{-I_b \times \beta r_e}{-\beta I_b} = R_E // r_e = 1.2k // 8.9 = \underline{\underline{8.9\Omega}}$$

$$V_{in} = -(I_b \times \beta r_e)$$

$$A_V = \frac{V_o}{V_{in}} = \frac{-\beta I_b \times R_C}{-(I_b \times \beta r_e)} = \frac{R_C}{r_e} = \frac{2.2k}{8.9} = \underline{\underline{247.2}}$$

$$A_I = \frac{I_o}{I_{in}} = A_V \frac{R_{in}}{R_C} = \frac{R_C}{r_e} \times \frac{R_E // r_e}{R_C} = \frac{R_E // r_e}{r_e} = \frac{r_e}{r_e} \underline{\underline{= 1}} \Leftarrow (R_E >> r_e)$$