Analog Electronics
ENEE236

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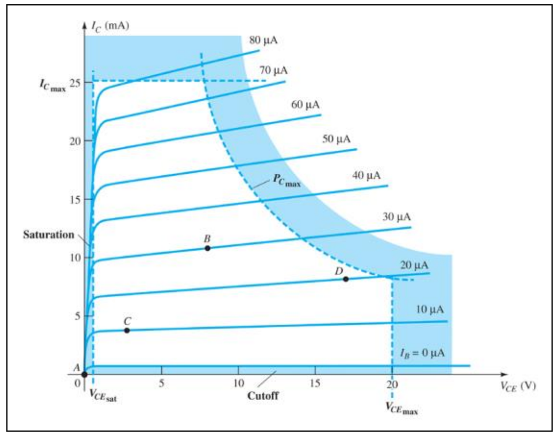
L8- DC Biasing - BJTs

Biasing

Biasing: Applying DC voltages to a transistor in order to establish fixed level of voltage and current.
For Amplifier (active/Linear) mode, the resulting dc voltage and current establish the operation point to turn it on so that it can amplify AC signals.

Operating Point

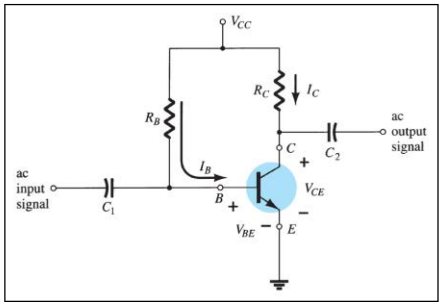
The DC input establishes an operating or *quiescent point* called the ***Q-point***.



DC Biasing Circuits

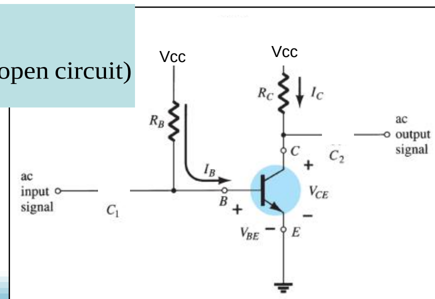
1. **Fixed-bias circuit**
2. **Emitter-stabilized bias circuit**
3. **DC bias with voltage feedback**
4. **Voltage divider bias circuit**

1)Fixed Bias Configuration



DC equivalent circuit

$$f = 0 \Rightarrow Xc = \frac{1}{2\pi fC} \cong \infty \text{ (open circuit)}$$



The Base-Emitter Loop

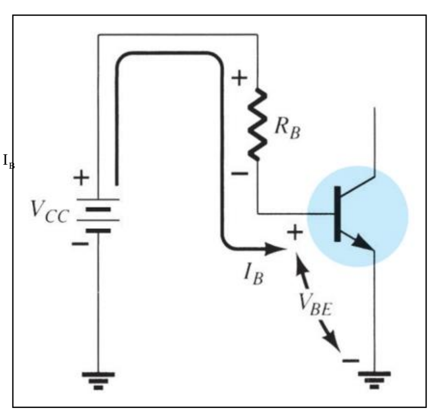
From Kirchhoff's voltage law for Input:

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

Solving for base current:

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

Choosing R_B will establish the required level of I_B



Collector-Emitter Loop

Collector current:

$$I_C = \beta I_B$$

From Kirchhoff's voltage law:

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

$$V_{CE} = V_C - V_E$$

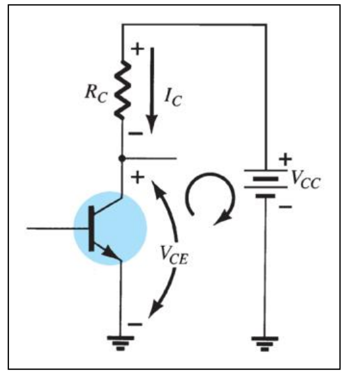
Since $V_E = 0$ ⇨ $\therefore V_{CE} = V_C$

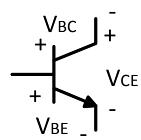
$$V_{CE} = V_{CC} - I_C R_C$$

Also

$$V_{BE} = V_B - V_E$$

$$\therefore V_{BE} = V_B$$





$$V_{BE} - V_{CE} - V_{BC} = 0$$

$$\therefore V_{BC} = V_{BE} - V_{CE}$$

Design: Fixed bias

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

Design for Q-point: $V_{CEQ} = 5V$, $I_{CQ} = 1mA$

Solution

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

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

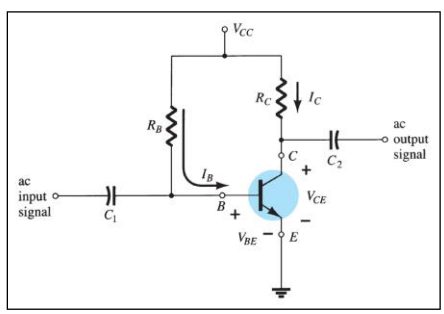
$$R_B = \frac{V_{CC} - V_{BE}}{I_B} = \frac{10 - 0.7}{10\,\mu A}$$

$$= 930\,k\Omega$$

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

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

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

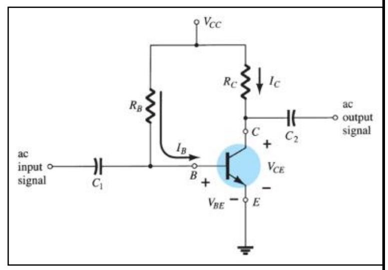


Fixed bias Stability

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

Design for Q-point: $V_{CEQ} = 5V$, $I_{CQ} = 1mA$

Solution – continued



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

$I_B = 10\,\mu A$

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

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

$V_{CEQ} = 10 - (0.5\,mA)(5\,k\Omega) = 7.5\,V$

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

$I_B = 10\,\mu A$

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

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

$V_{CEQ} = 10 - (1.5\,mA)(5\,k\Omega) = 2.5\,V$

for

$50 \le \beta \le 150$

$I_B = 10\,\mu A$ fixed

$0.5\,mA \le I_C \le 1.5\,mA$

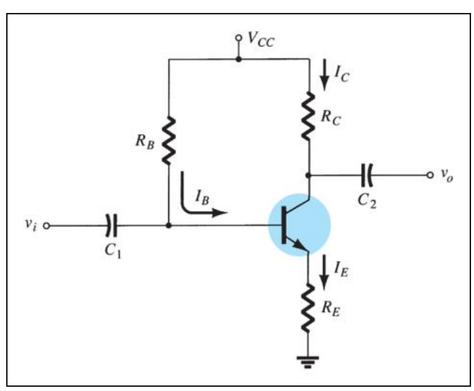
$7.5\,V \ge V_{CE} \ge 2.5\,V$

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

Not very stable

2) Emitter-Stabilized Bias Circuit

Adding a resistor (R_E) to the emitter circuit stabilizes the bias circuit.



Base-Emitter Loop

From Kirchhoff's voltage law:

$$+V_{CC} - I_B R_B - V_{BE} - I_E R_E = 0$$

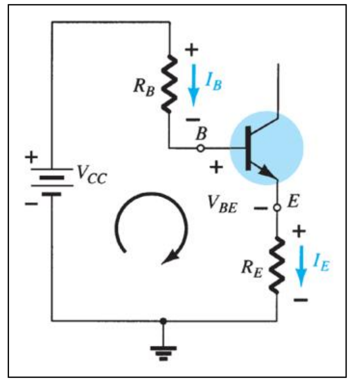
Since $I_E = (\beta + 1)I_B$:

$$V_{CC} - I_B R_B - V_{BE} - (\beta+1) I_B R_E = 0$$

Solving for I_B:

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

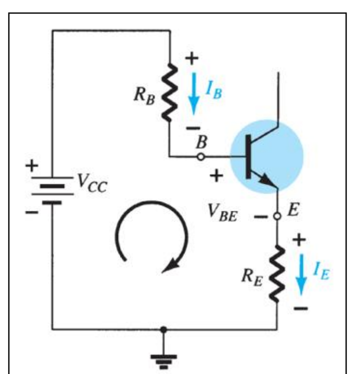
$(\beta+1)R_E$ ← is the emitter resistor as it appears in the base emitter loop



Base-Emitter Loop

Solving for I_E:

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



In order to get IE almost independant of B we choose:

$$R_E >> \frac{R_B}{(\beta+1)}$$

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

Also, in order to guarantee operation in linear mode we choose $0.1 V_{CC} \le V_E < 0.2 V_{CC}$

Collector-Emitter Loop

From Kirchhoff's voltage law:

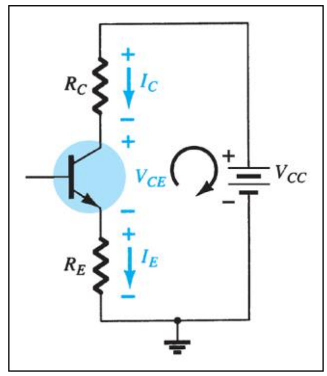
$$I_E R_E + V_{CE} + I_C R_C - V_{CC} = 0$$

Since $I_E \cong I_C$:

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

Also:

$$V_E = I_E R_E$$
$$V_C = V_{CE} + V_E = V_{CC} - I_C R_C$$
$$V_B = V_{CC} - I_R R_B = V_{BE} + V_E$$



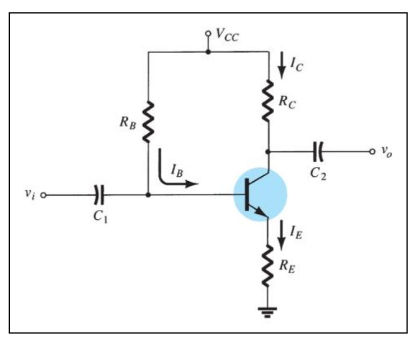
Design: Emitter Stabilization bias

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

Design for Q-point: $V_{CEQ} = 5V$, $I_{CQ} = 1mA$

Solution

$$-\text{let } V_E = 0.1 V_{CC}$$
$$V_E = 1V$$
$$I_E = \frac{V_E}{R_E} \Rightarrow R_E = \frac{1\,V}{1.01\,mA} \cong 1\,k\Omega$$
$$I_B = \frac{V_{CC} - V_{BE}}{R_B + (\beta+1)R_E} \Rightarrow$$
$$R_B I_B + I_B(\beta+1)R_E = V_{CC} - V_{BE}$$
$$R_B = \frac{V_{CC} - V_{BE} - I_B(\beta+1)R_E}{I_B}$$
$$= \frac{10 - 0.7 - 10\,\mu A(100+1)1\,k\Omega}{10\,\mu A}$$
$$= 829\,k\Omega$$



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

Emitter bias Stability

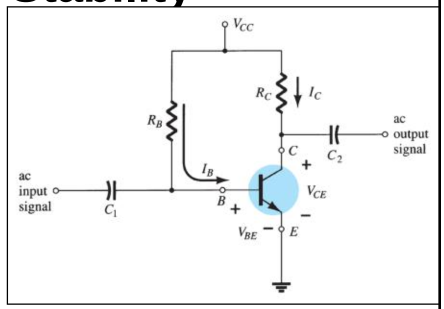
If $\beta = \beta_{min} = 50$

$$I_B = \frac{9.3}{829k\Omega + 51k\Omega} = 10.56\,\mu A$$

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

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

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



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

$$I_B = \frac{9.3}{829k\Omega + 151k\Omega} = 9.489\,\mu A$$

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

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

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

for

$50 \le \beta \le 150$

$10.56\,\mu A \ge I_B \ge 9.489\,\mu A$

$0.528\,mA \le I_C \le 1.423\,mA$

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

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

Improved, but not very stable

Improved Biased Stability

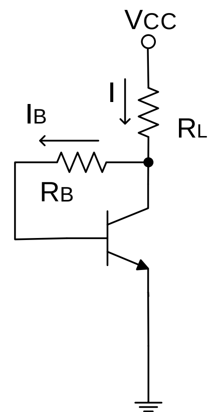
Stability refers to a condition in which the currents and voltages remain fairly constant over a wide range of temperatures and transistor Beta (β) values.

Adding R_E to the emitter improves the stability of a transistor.

3) DC Bias With Voltage Feedback

Another way to improve the stability of a bias circuit is to add a feedback path from collector to base.

In this bias circuit the Q-point is only slightly dependent on the transistor beta, β.



Base-Emitter Loop

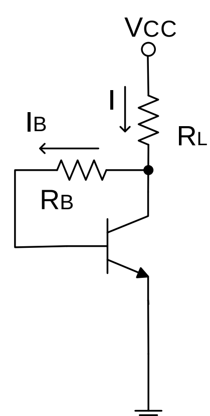
From Kirchhoff's voltage law:

$$V_{CC} - I.R_L - I_B R_B - V_{BE} = 0$$
$$I = I_C + I_B$$
$$I_C = \beta I_B$$

Solving for I_B:

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

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



suppose $\beta\uparrow, I_B\downarrow, I_C = \uparrow\beta.I_B\downarrow \cong$ const

there is some kind of compensation effect

Design: Voltage feedback bias

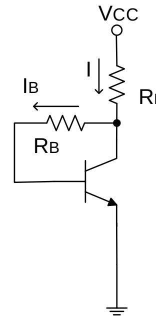
Assume $VCC = 10V, \beta_{nominal} = 100, \beta_{min} = 50, \beta_{max} = 150$

Design for Q-point : $V_{CEQ} = 5V, I_{CQ} = 1mA$

Solution

$$R_L = \frac{V_{CC} - V_{CE}}{I_C + I_B} = \frac{10-5}{1mA + \frac{1mA}{100}}$$

$$= 4.95\ k\Omega$$



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

$$\therefore R_B = 430\ k\Omega$$

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

$I_B = 0.013627\ mA$

$I_C = 0.68\ mA$

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

$I_B = 0.00793\ mA$

$I_C = 1.19\ mA$

for

$50 \le \beta \le 150$

$0.68\ mA \le I_C \le 1.19\ mA$

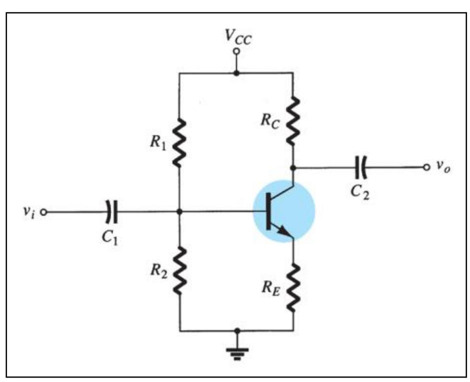
$$\therefore \frac{I_{C(max)}}{I_{C(min)}} = \frac{1.19\ mA}{0.68\ mA} \cong 1.75$$

Better Q-point stability

4) Voltage Divider Bias

This is a very stable bias circuit.

The currents and voltages are nearly independent of any variations in β if the circuit is designed properly



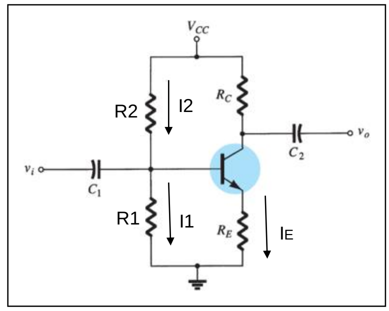
Approximate Analysis

Where $I_B << I_1$ and $I_1 \cong I_2$:

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

$$V_E = V_B - V_{BE}$$

$$I_{E(approximate)} = \frac{V_E}{R_E} = \frac{V_B - V_{BE}}{R_E}$$



From Kirchhoff's voltage law:

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

$$I_E \cong I_C$$

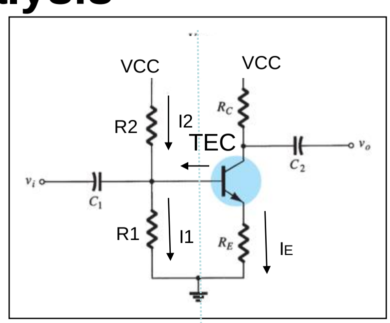
$$V_{CE} = V_{CC} - I_C (R_C + R_E)$$

Here we got Ic independent of β which provides good Q-point stability

Exact Analysis

We must try to make I_B as close as possible to zero

Thevenin Equivalent circuit for the circuit left of the base is done



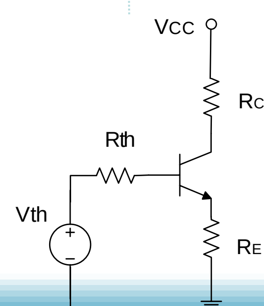
$$V_{th} = \frac{R_1 V_{CC}}{R_1 + R_2}$$

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

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

$$\text{but } I_B = \frac{I_E}{\beta + 1}$$

$$\therefore I_{E(exact)} = \frac{V_{th} - V_{BE}}{\frac{Rth}{\beta + 1} + R_E}$$



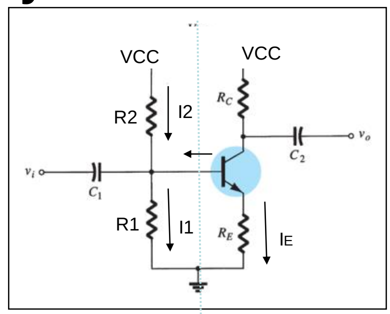
Exact Analysis

$$\therefore I_{E(exact)} = \frac{V_{th} - V_{BE}}{\frac{Rth}{\beta+1} + R_E}$$

if we compare to approximate solution

$$I_{E(approximate)} = \frac{V_B - V_{BE}}{R_E}$$

$$\Rightarrow \text{we must make the quantity } \frac{Rth}{\beta+1} << R_E$$



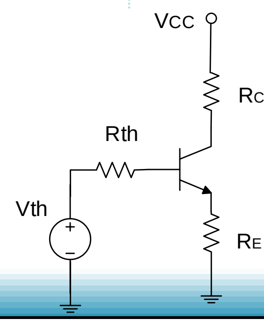
Here we got Ic independent of β

$$\therefore \quad Rth << (\beta+1)R_E$$

$$\text{as a rule let } Rth << \frac{(\beta+1)R_E}{10}$$

or

$$Rth << \frac{\beta R_E}{10}$$



Design: Voltage Divider bias

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

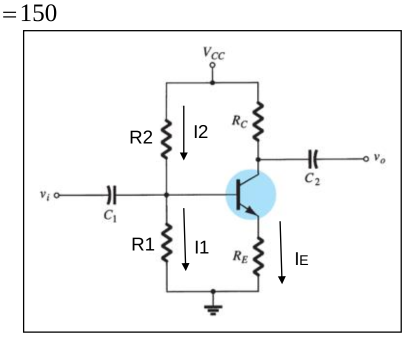
Design for Q-point : $V_{CEQ} = 5V, I_{CQ} = 1mA$

Solution

1)let $V_E = 0.1 V_{CC}$

$V_E = 1V$

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



$$2) \text{ let } Rth = \frac{R_E.\beta_{nominal}}{50} = \frac{1k\Omega.100}{50} = 2k\Omega$$

$$3) \ V_{CC} = R_C I_C + I_E R_E + V_{CE}$$

$V_{CEQ} = 5$

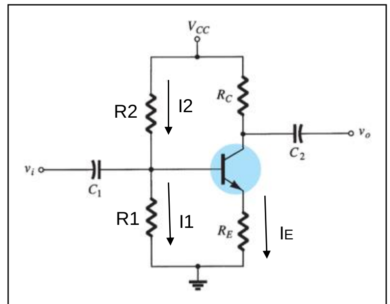
$$\therefore R_C = \frac{V_{CC} - V_{CE} - V_E}{1mA} = \frac{10-5-1}{1mA} = 4k\Omega$$

Design: Voltage Divider bias

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

Design for Q-point : $V_{CEQ} = 5V$, $I_{CQ} = 1mA$

Solution – continued



$$4) I_E = \frac{V_{th} - V_{BE}}{\frac{Rth}{\beta+1} + R_E}$$

$$\therefore V_{th} = \frac{R_1 V_{CC}}{R_1 + R_2} = I_E\left(\frac{Rth}{\beta+1} + R_E\right) + V_{BE} = 1.72V \quad ...(1)$$

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

solving (1) & (2) yields:

$R_1 = 2.42 \ k\Omega$

$R_2 = 11.64 \ k\Omega$

Voltage Divider bias Stability

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

$I_C = 0.982 \ mA$

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

$I_C = 1.0069 \ mA$

for

$50 \le \beta \le 150$

$0.982 \ mA \le I_C \le 1.0067 \ mA$

$$\therefore \frac{I_{C(max)}}{I_{C(min)}} = \frac{1.0067 \ mA}{0.982 \ mA} \cong 1.0254$$

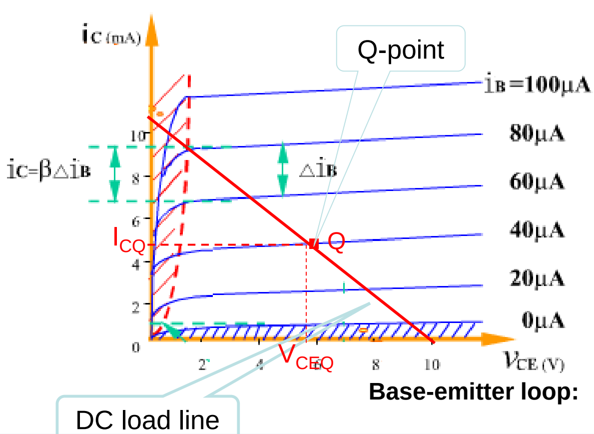
Very good Q-point stability

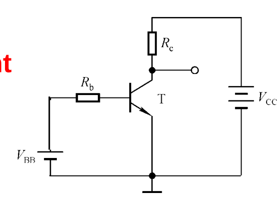
PNP Transistors

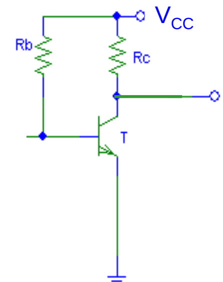
The analysis for *pnp* transistor biasing circuits is the same as that for *npn* transistor circuits. The only difference is that the currents are flowing in the opposite direction.

Basic BJT Amplifiers Circuits

DC Load Line and Quiescent Operation Point







Base-emitter loop: $I_B = \frac{V_{CC} - V_{BE}}{R_b} \approx \frac{V_{CC}}{R_b} = 40(\mu A)$

Collector-emitter loop: $v_{CE} = V_{CC} - i_C R_C = 10 - i_C \times 4k$

DC and AC Load Lines

Assume VCC = 18V, β = 100

$R_B = 576\ k\Omega;\ R_C = 3k\Omega;\ V_{BE} = 0.65\ V$

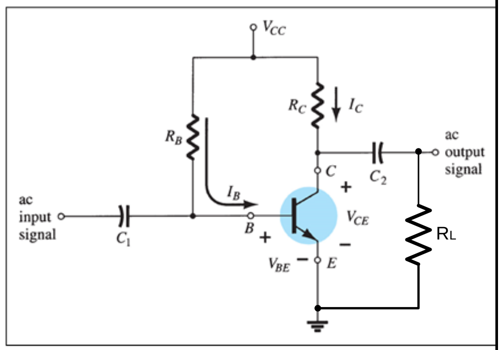
FIRST: DC ANALYSIS

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

$$I_C = -\frac{1}{R_C} V_{CE} + \frac{V_{CC}}{R_C} \Leftarrow I_C = f(V_{CE})$$

This is a straight line equation

$$Y = mX + b$$



$$I_B = \frac{V_{CC} - V_{BE}}{R_B} = \frac{18 - 0.65}{576\ k\Omega} = 30\ \mu A$$

$$I_C = \beta I_B = 3\ mA$$

$$V_{CE} = V_{CC} - I_C R_C = 18 - (3mA)(3k\Omega)$$
$$= 9\ V$$

DC Load Line

I_{Csat}

$$I_{Csat} = \frac{V_{CC}}{R_C}$$

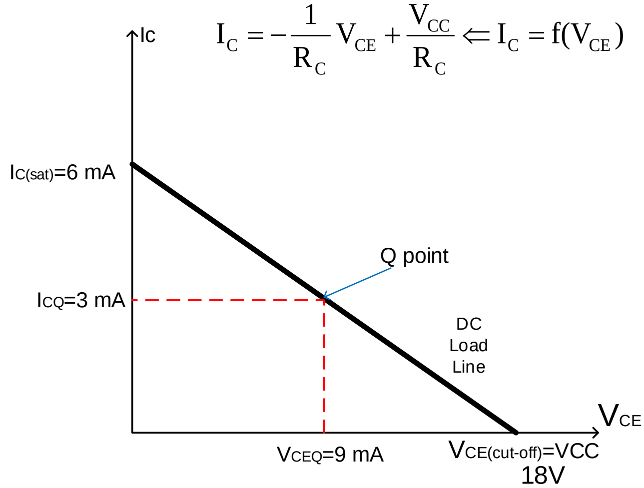
$$V_{CE} = V_{CE(sat)} \cong 0\ V$$

$V_{CEcutoff}$

$V_{CE(cutoff)} = V_{CC}$

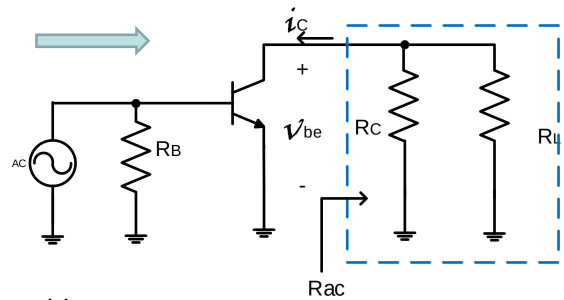
$I_C = 0$ mA

$$I_C = -\frac{1}{R_C} V_{CE} + \frac{V_{CC}}{R_C} \Leftarrow I_C = f(V_{CE})$$



AC Load Line

AC Equivalent Circuit



Since we have dc and ac quantities,

let us define the notation

total DC ac

$V_{BE}(t) = \mathrm{V_{BE}} + v_{be}$

$V_{CE}(t) = \mathrm{V_{CE}} + v_{ce}$

$I_C(t) = \mathrm{I_C} + i_c$

$I_B(t) = \mathrm{I_B} + i_b$

$v_{ce} = -R_{ac}.i_c$

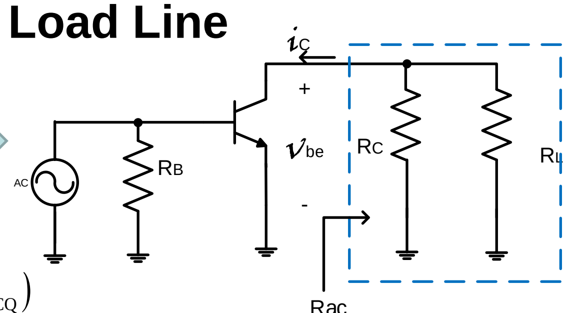
where $R_{ac} = R_c // R_L$

is the ac resistance seen from collector terminal

+ resistance seen from emitter terminal

AC Load Line

AC Equivalent Circuit



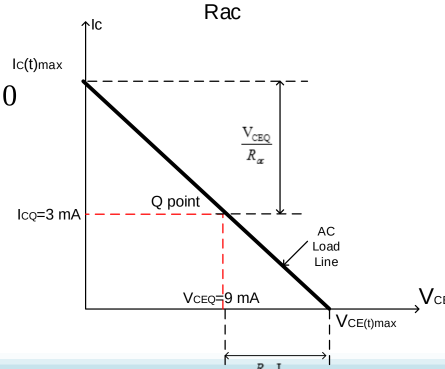
$$\left(V_{CE}(t) - \mathrm{V_{CEQ}}\right) = -R_{ac}.\left(I_C(t) - \mathrm{I_{CQ}}\right)$$

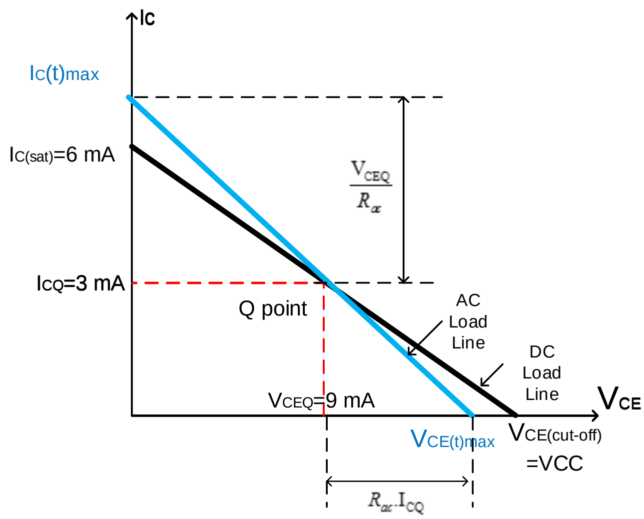
$$\left(V_{CE}(t)_{\max} - \mathrm{V_{CEQ}}\right) = R_{ac}.\mathrm{I_{CQ}}$$

$$V_{CE}(t)_{\max} = \mathrm{V_{CEQ}} + R_{ac}.\mathrm{I_{CQ}} \text{ , when } I_C(t) = 0$$

$$\left(V_{CE}(t) - \mathrm{V_{CEQ}}\right) = -R_{ac}.\left(I_C(t) - \mathrm{I_{CQ}}\right)$$

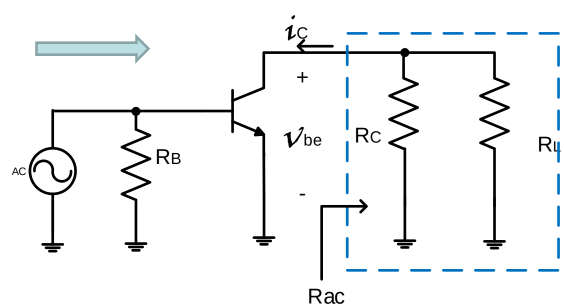
$$I_C(t)_{\max} = \frac{\mathrm{V_{CEQ}}}{R_{ac}} + \mathrm{I_{CQ}} \text{ when } V_{CE}(t) = 0$$





AC Load Line

AC Equivalent Circuit



$$v_{ce} = V_{CE}(t) - \mathrm{V_{CE}}$$
$$i_c = I_C(t) - \mathrm{I_C}$$

$$v_{ce} = -R_{ac}.i_c$$

$$\left(V_{CE}(t) - \mathrm{V_{CEQ}}\right) = -R_{ac}.\left(I_C(t) - \mathrm{I_{CQ}}\right)$$

Ac load line equation

To Draw ac load line
we find $\left(V_{CE}(t)_{\max}\right) and \left(I_C(t)_{\max}\right)$

Design Criteria

- In order to have the amplifier to amplify an input ac signal without distortion (by going into saturation or cut-off)
- We must choose the Q-point in the middle of ac load line

$$I_{CQ} = \frac{1}{2} I_C(t)_{max}$$

$$V_{CEQ} = \frac{1}{2} V_{CE}(t)_{max}$$

$$\Rightarrow$$

$$2I_{CQ} = I_C(t)_{max}$$

$$2I_{CQ} = I_{CQ} + \frac{V_{CEQ}}{R_{ac}}$$

$$\therefore I_{CQ} = \frac{V_{CEQ}}{R_{ac}}$$

DC Analysis

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

$$\text{define } R_{dc} = R_C$$

$$V_{CC} = V_{CE} + I_C R_{dc}$$

at the Q-point

$$V_{CC} = V_{CEQ} + I_{CQ} R_{dc}$$

For maximum Symmetrical swing

$$\Downarrow$$

$$I_{CQ} = \frac{V_{CEQ}}{R_{ac}} \Rightarrow V_{CEQ} = I_{CQ} R_{ac}$$

$$V_{CC} = I_{CQ}.R_{ac} + I_{CQ}.R_{dc}$$

$$\therefore I_{CQ} = \frac{V_{CC}}{R_{ac} + R_{dc}}$$

$\Leftarrow$ **** To design for maximum Symmetrical Swing

DC Analysis

Also

$$V_{CEQ} = V_{CC} - I_{CQ} R_{dc}$$

$$= V_{CC} - R_{dc} \frac{V_{CC}}{R_{ac} + R_{dc}}$$

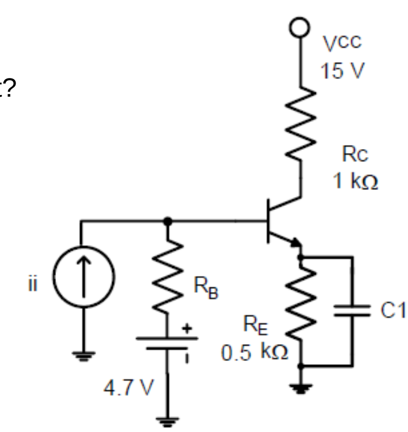
$$= V_{CC} \left(1 - \frac{R_{dc}}{R_{ac} + R_{dc}} \right)$$

$$= V_{CC} \left(\frac{R_{ac} + R_{dc} - R_{dc}}{R_{ac} + R_{dc}} \right)$$

$$= V_{CC} \left(\frac{R_{ac}}{R_{ac} + R_{dc}} \right) = \left(\frac{V_{CC}}{1 + \frac{R_{dc}}{R_{ac}}} \right)$$ ***** For maximum Symmetrical swing

Design Example

Design the amplifier for maximum symmetrical swing of the collector current?
Find the Q-point?
Find the required Value of RB?
Draw AC and DC load lines
What is the power dissipation of the transistor at the Q-point?



Solution

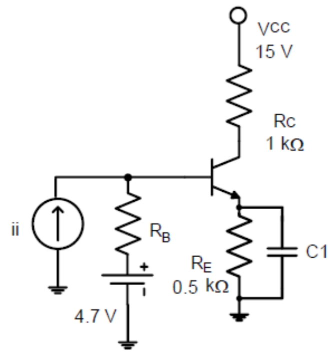
$$R_{ac} = R_C = 1\ k\Omega$$

$$R_{dc} = R_C + R_E = 1.5\ k\Omega$$

For Maximum Symmetrical Swing of Ic

$$I_{CQ} = \frac{V_{CC}}{R_{ac} + R_{dc}} = \frac{15}{1\ k\Omega + 1.5\ k\Omega} = 6\ mA$$

$$V_{CEQ} = \frac{V_{CC}}{1 + \frac{R_{dc}}{R_{ac}}} = \frac{15}{1 + \frac{1.5\ k\Omega}{1\ k\Omega}} = 6\ V$$



Maximum Swing (peak) of Ic

$$I_{CM} = I_{CQ} = 6\ mA$$

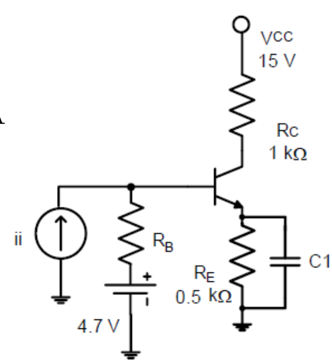
Maximum Symmetrical Swing (peak - peak) of Ic

$$I_{Cp\text{-}p} = 2I_{CQ} = 12\ mA$$

Solution

Maximum value of Ic:

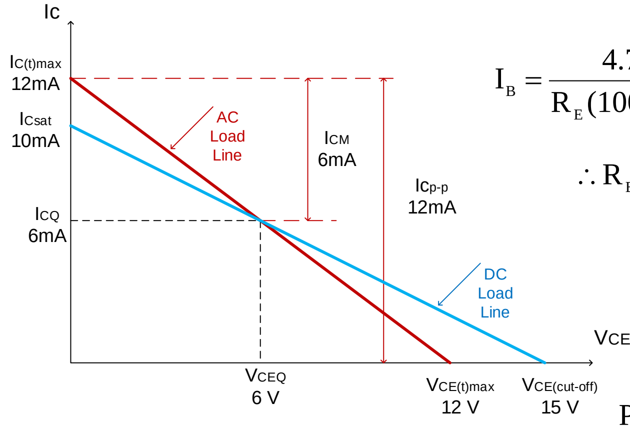
$$I_C(t)_{Max} = I_{CQ} + \frac{V_{CEQ}}{R_{ac}} = 6\ mA + \frac{6}{1\ k\Omega} = 12\ mA$$



Maximum Value of V_{CE}

$$V_{CE}(t)_{Max} = I_{CQ}R_{ac} + V_{CEQ} = 6\ mA.1\ k\Omega + 6 = 12\ V$$

Example -Continued



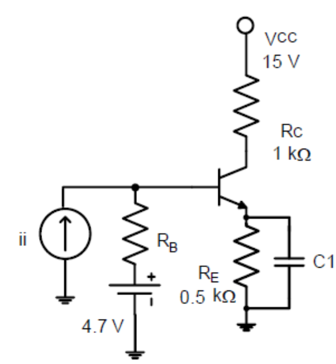
$$I_B = \frac{4.7 - 0.7}{R_E(100+1) + R_B} = \frac{I_{CQ}}{100} = 60\,\mu A$$

$$\therefore R_B = 33\,k\Omega$$

$$P_Q = V_{CEQ}.I_{CQ}$$
$$= 6V.6mA = 36\,mW$$
$$= 6V.6mA = 36\,mW$$

Analysis Example

Given RB=50 kΩ
Find the maximum collector current swing and the Q-point?
Draw AC and DC load lines
What is the power dissipation of the transistor at the Q-point?



Solution

$$R_{ac} = R_C = 1\ k\Omega$$

$$R_{dc} = R_C + R_E = 1.5\ k\Omega$$

Value of I_B and Ic

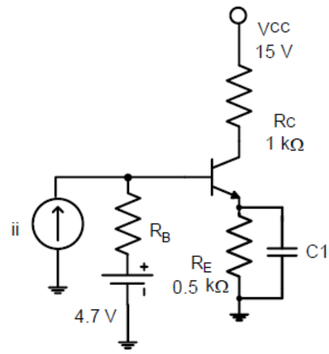
$$I_B = \frac{4.7 - 0.7}{R_E(100+1) + R_B}$$

$$= \frac{4.7 - 0.7}{500(100+1) + 50k\Omega}$$

$$= 40\ \mu A$$

$$I_{CQ} = \beta I_{BQ} = 4\ mA$$

$$V_{CEQ} = V_{CC} - I_{CQ}(R_C + R_E) = 9\ V$$



Maximum Swing (peak) of Ic

$$I_{CM} \neq I_{CQ}, \Rightarrow I_{CM} = 4\ mA$$

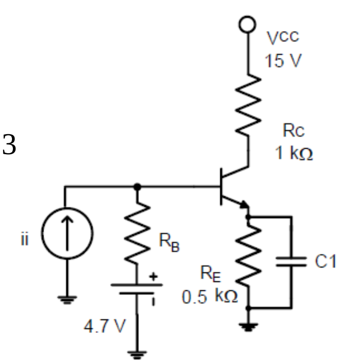
Maximum Symmetrical Swing (peak - peak) of Ic

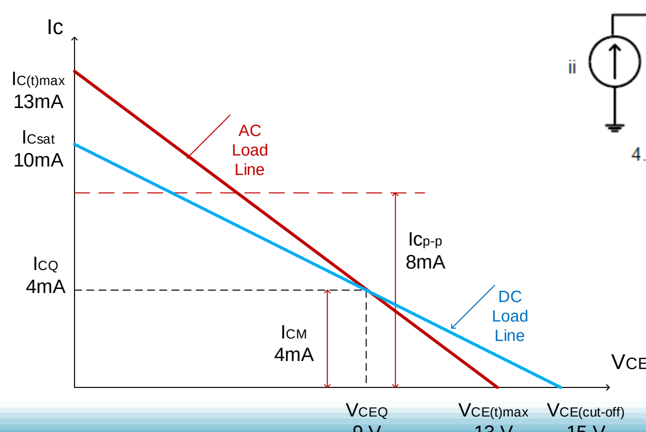
$$I_{Cp\text{-}p} = 2I_{CM} = 8\ mA$$

Solution

$$I_C(t)_{Max} = I_{CQ} + \frac{V_{CEQ}}{R_{ac}} = 4\ mA + \frac{9}{1\ k\Omega} = 13\ mA$$

$$V_{CE}(t)_{Max} = I_{CQ}R_{ac} + V_{CEQ} = 4\ mA.1\ k\Omega + 9 = 13$$



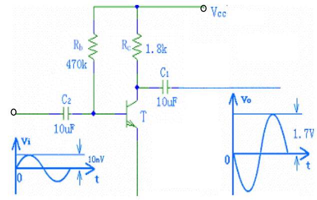


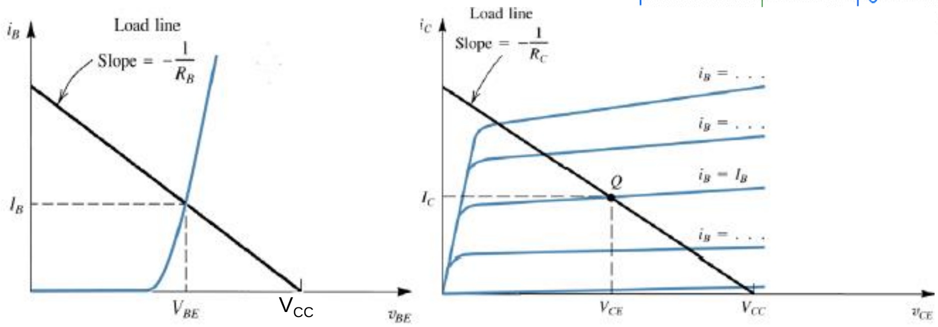
Maximum Swing was reduced because the Q-point was not placed properly

Basic BJT Amplifiers Circuits

Graphical Analysis

- Can be useful to understand the operation of BJT circuits.
- First, establish DC conditions by finding I_B (or V_{BE})
- Second, figure out the DC operating point for I_C



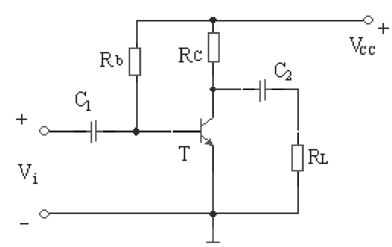


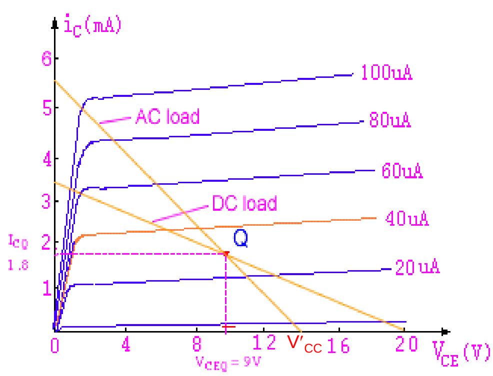
Can get a feel for whether the BJT will stay in active region of operation

– What happens if R_C is larger or smaller?

Basic BJT Amplifiers Circuits

Graphical Analysis





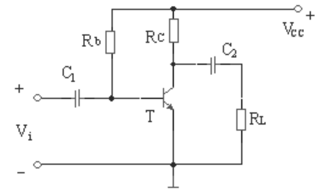
$$v_{ce} = -i_c(R_C // R_L) = -i_c R_L^{'}$$

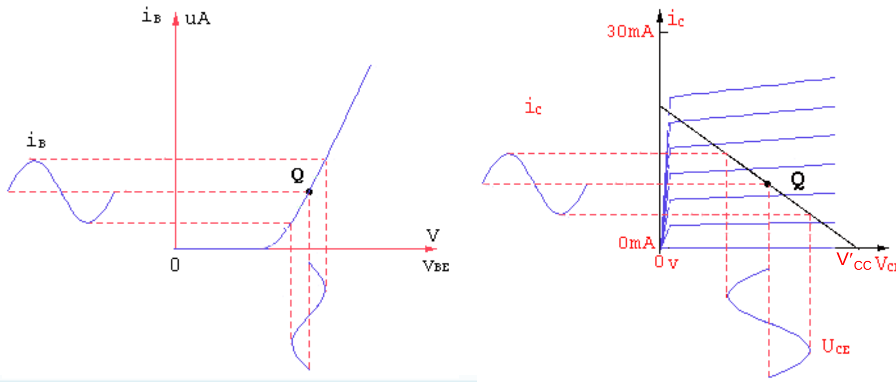
$$V_{CC}' = V_{CEQ} + I_{CQ} R_L'$$

Basic BJT Amplifiers Circuits

Graphical Analysis

Q-point is centered on the ac load line:

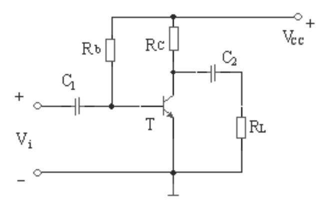


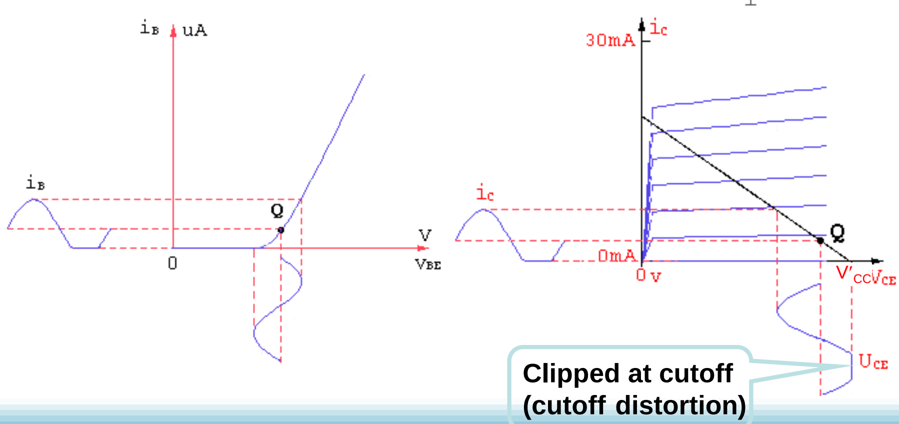


Basic BJT Amplifiers Circuits

Graphical Analysis

Q-point closer to cutoff:

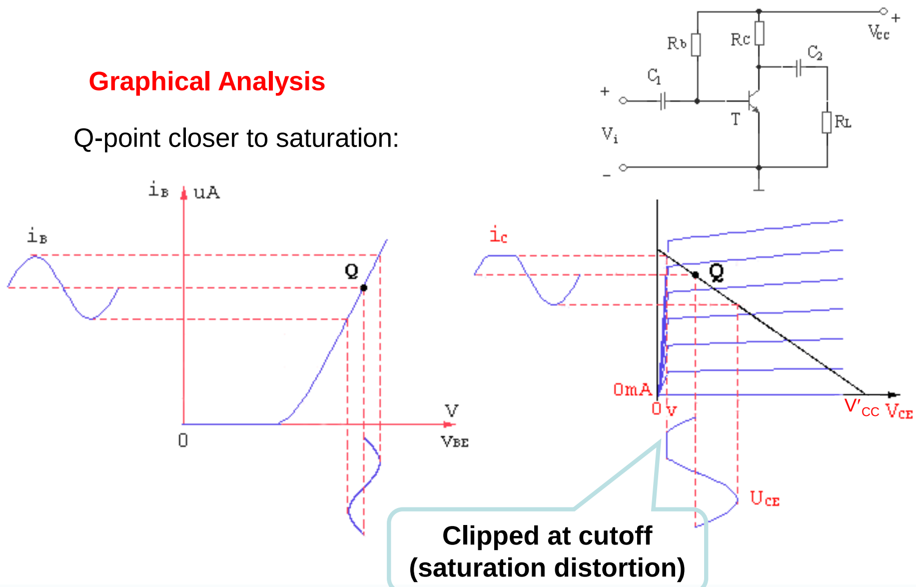




Basic BJT Amplifiers Circuits

Graphical Analysis

Q-point closer to saturation:



Basic BJT Amplifiers Circuits

Graphical Analysis