Topic 1.2 : Bias stability

Variation of Q-point (or) Factors Affecting stability of Q-point

* The biasing circuit should be designed to fix the operating point (or Q-point at the centre of the active region.
* But only fixing of the operating point is not sufficient.
* While designing the biasing circuit, care should be taken so that the Q-point will not shift into an undesirable region (ie cutoff or saturation)
* Designing the bias circuit to stabilize the Q-point is taken as bias stability.

Temperature

1) I_{CO}

* The flow of current in the circuit produces heat at the junctions.
* This heat increases the temperature at the junctions.
* We know that the minority carriers are temperature dependent
* They increase with Temperature.
* The increase in the minority carriers increases the leakage current I_{CEO}.

$$\because I_{CEO} = (1+\beta) I_{CBO}$$

* I_{CBO} doubles for every $10°C$ rise in temperature.

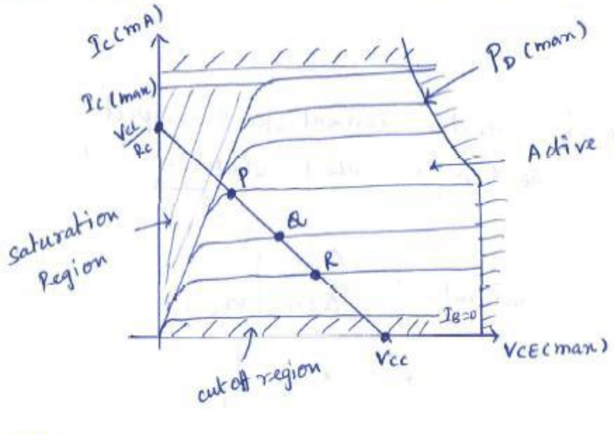
* Increase in I_{CEO} in turn Increase in the collector current.

$$\therefore I_C = \beta I_B + I_{CEO}$$

* The increase in I_C further raises the temperature at the collector junction & the same cycle repeats.
* The excessive increase in I_C shifts the Q-point into the saturation region, changing the operating condition set by biasing circuit.
* The power dissipation at collector base junction is

$$P_D = V_C I_C$$

* The increase in the I_C increases the power dissipated at the collector junction.
* This in turn further increase the temperature of the junction & hence increase the I_C.
* The power is cumulative.
* The excess heat produced at the collector base junction may even burn & destroy the transistor.
* This situation is called Thermal runaway of the transistor.
* For any Transistor the maximum power dissipation is always a fixed value.
* This known as maximum power dissipation rating of a Transistor.



* The hyperbola give the maximum power dissipation for Transistor
* If this limit is crossed the device will fail.

2) VBE

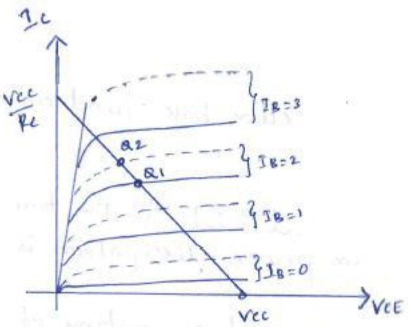
* V_{BE} changes with temperature at the rate of 2.5 mV/°C
* I_B depends upon V_{BE}
* I_B depends on V_{BE} & I_C depends on I_B. I_C depends on V_{BE}.
* ∴ I_C changes with temperature due to changes in V_{BE}
* The change in I_C changes the Q-point.

3) β_{dc}

* It's also temperature dependent.
* As β_{dc} varies, I_C also varies, since $I_C = \beta I_B$
* The change in I_C change the Q-point.

Transistor current gain h_{FE} | β

* There are changes in the Transistor parameters among different units of the same type, same number.
* If we take 2 transistor units of same type & use them in the circuit, there is change in the β value in actual practice.
* The biasing circuit is designed according to the required β value.
* But due to change in β from unit to unit, the Q-point may shift.



* This fig: shows the CE o/p characteristics for 2 Transistor of the same type.
* The dashed characteristics are for a Transistor whose β is much larger than that of the Transistor represent by solid curves.

Stability Factors

S:

* The rate of change of collector current (I_C) with respect to collector leakage current (I_{CO}) at constant V_{BE} & β is called stability factor.

$$S = \frac{\partial I_C}{\partial I_{CO}}\bigg|_{V_{BE} \,\&\, \beta \text{ constant}} = \frac{\Delta I_C}{\Delta I_{CO}}\bigg|_{V_{BE} \,\&\, \beta \text{ constant}}$$

$$= \frac{\Delta I_{C2} - \Delta I_{C1}}{\Delta I_{CO2} - \Delta I_{CO1}}\bigg|_{V_{BE} \,\&\, \beta \text{ constant}}$$

S':

* The rate of change of collector current (I_C) with respect to V_{BE} at constant I_{CO} & β is called stability factor S'.

$$S' = \frac{\partial I_C}{\partial V_{BE}}\bigg|_{I_{CO} \,\&\, \beta \text{ constant}} = \frac{\Delta I_C}{\Delta V_{BE}}\bigg|_{I_{CO} \,\&\, \beta \text{ constant}} = \frac{\Delta I_{C2} - \Delta I_{C1}}{\Delta V_{BE_2} - \Delta V_{BE_1}}\bigg|_{I_{CO} \,\&\, \beta \text{ constant}}$$

S'':

* The rate of change of collector current (I_C) with respect to β at constant I_{CO} & V_{BE} is called <u>stability factor S''</u>.

$$S'' = \left.\frac{\partial I_C}{\partial \beta}\right|_{I_{CO}\ \&\ V_{BE}\ \text{constant}} = \left.\frac{\Delta I_C}{\Delta \beta}\right|_{I_{CO}\ \&\ V_{BE}\ \text{constant}}$$

$$= \left.\frac{\Delta I_{C2} - \Delta I_{C1}}{\Delta \beta_2 - \Delta \beta_1}\right|_{I_{CO}\ \&\ V_{BE}\ \text{constant}}$$

The total change in collector current over a specified temperature range is obtained by expressing this change as the sum of individual changes due to 3 stability factors.

$$\Delta I_C = S \Delta I_{CO} + S' \Delta V_{BE} + S'' \Delta \beta$$