Topic 1.6 : Bias Compensation

Bias compensation / Methods of stabilizing the Q-point

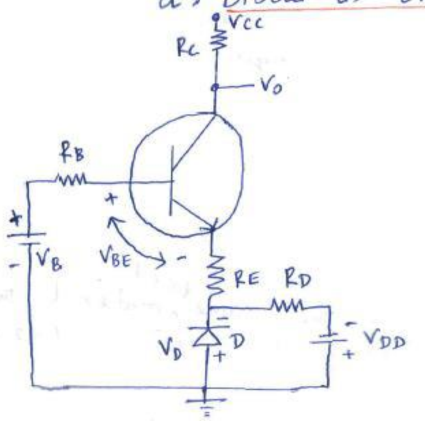
* The compensation Techniques uses Temperature sensitive devices such as diodes, Transistors, Thermistors etc.. to maintain the operating point constant.

1. Diode compensation Techniques
   1. compensation for V_{BE}
      a) Diode in Emitter circuit
      b) Diode in Voltage Divider circuit
   2. compensation for I_{co}
2. Thermistor compensation Technique
3. Sensistor compensation Technique

1. Diode Compensation Technique

1. Compensation for V_{BE}

a) Diode in Emitter circuit



* Here, separate supply VDD is used to Keep diode in Forward bias condition.

* If the diode & Transistor are of same material, The voltage across the Diode will have the same temperature coefficient ($-2.5\ mV/^\circ C$) as the V_{BE}.

* So the V_{BE} changes by ∂V_{BE} with change in temperature, V_D changes by ∂V_D &

$\partial V_D' \simeq \partial V_{BE}$. The change tend to cancel each other.

* We know,

$$V_{BE} = V_T - \left[\frac{R_B + (1+\beta)R_E}{\beta}\right] I_c + \left[\frac{(R_E + R_B)(1+\beta)}{\beta}\right] I_{co}$$

$$\left[\frac{R_B + (1+\beta)R_E}{\beta}\right] I_c = V_T - V_{BE} + \left[\frac{(R_E + R_B)(1+\beta)}{\beta}\right] I_{co}$$

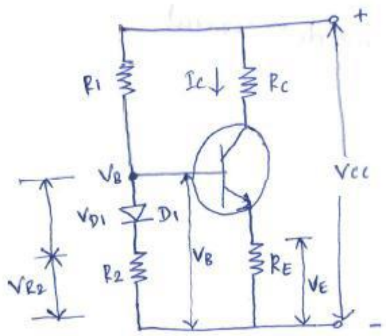
$$I_c = \frac{\beta[V_T - V_{BE}] + \cancel{\beta}\left[\frac{(R_E + R_B)(1+\beta)I_{co}}{\cancel{\beta}}\right]}{R_B + (1+\beta)R_E}$$

* We modify the equation

$$I_C = \frac{\beta [V - (V_{BE} - V_D)] + (R_E + R_B)(1+\beta) I_{CO}}{R_B + (1+\beta) R_E}$$

* I_C will be insensitive to variations in V_{BE}.

b) Diode in voltage Divider circuit



* Here, the diode is connected in series with resistance R_2 in the voltage divider circuit & it is in forward bias condition.
* We derived for voltage divider bias

$$I_E = \frac{V_B - V_{BE}}{R_E}$$

also $I_E = \frac{V_E}{R_E}$ & $I_C \simeq I_E$.

$$I_C \simeq \frac{V_B - V_{BE}}{R_E} \quad — ①$$

* When V_{BE} change with temperature I_C also changes.
* The voltage at the base V_B is now

$$V_B = V_{R2} + V_D \quad — ②$$

* sub eqn ② in ①

$$① \Rightarrow I_C \simeq \frac{V_{R2} + V_D - V_{BE}}{R_E}$$

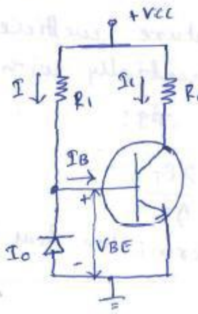
* If the diode & the Transistor are of the same type & material, the voltage across the diode will have the same temperature coefficient ($-2.5\,mV/°C$) as the V_{BE}.
* So the V_{BE} changes by ∂V_{BE} with change in temperature. V_D changes by ∂V_D & $\partial V_D \simeq \partial V_{BE}$. The change tend to cancel each other.
* The collector current as

$$I_C \simeq \frac{V_{R2}}{R_E}$$

* Which is unaffected due to change in V_{BE}.
* The biasing is provided by R_1, R_2 & R_E.
* The changes in V_{BE} due to temperature are compensated by changes in the diode voltage which keeps I_C stable at Q-point.

2. Compensation for I_{co} / Diode compensation for germanium Transistor

* In case of Ge, changes in I_{co} with Temperature are comparatively larger than Si Transistor.



* It plays more role in I_c stability than the change in V_{BE}.
* It offers stabilization against variation in I_{co}.
* Here, the diode is kept in reverse bias condition.
* In reverse bias condition the current flowing through diode is only the leakage current (I_o).

* If the diode & the Transistor are of the same type & material. The leakage current I_o of the diode will increase with temperature at the same rate as the collector leakage current I_{co}.

$$I = \frac{V_{cc} - V_{BE}}{R_1} \quad \& \quad I = I_B + I_o$$

$$\therefore I_B = I - I_o \quad \text{—} \text{①}$$

* For Ge Transistor $V_{BE} = 0.2V$, which is very small & neglecting change in V_{BE} with temperature.

* We can write

$$I \simeq \frac{V_{cc}}{R_1} \simeq \text{constant}$$

* We know

$$I_c = \beta I_B + (1+\beta) I_{co} \quad \text{—} \text{②}$$

sub ① in ②

$$\text{②} \Rightarrow I_c = \beta(I - I_o) + (1+\beta) I_{co}$$

$$= \beta I - \beta I_o + (1+\beta) I_{co}$$

* if $\beta >> 1$ we get

$$I_c = \beta I - \beta I_o + \beta I_{co}$$

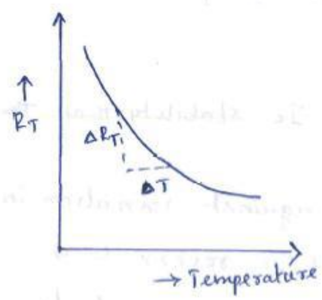
* We assume

$I_o = I_{co}$ we get

$$I_c = \beta I$$

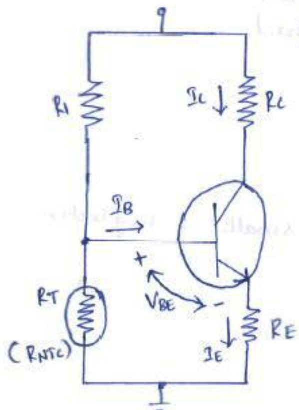
* As I is constant, I_c remains fairly constant.
* We can say that changes by I_{co} with temperature are compensated by diode & thus collector current remains fairly constant.

2. Thermistor compensation Technique



* This method uses Temperature sensitive devices such as Thermistors rather than diode (or) Transistor
* It has negative temperature coefficient. its resistance decreases exponentially with increasing Temperature : as shown in fig:
* slope of this curve $= \frac{\partial R_T}{\partial T}$

* The $\frac{\partial R_T}{\partial T}$ is the temperature coefficient for thermistor has negative temperature coefficient resistance (NTC).



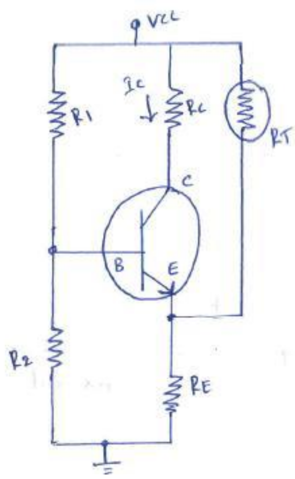
In This figure :

* R_2 is replaced by Thermistor R_T in self bias circuit.
* With increase in Temperature R_T decreases.
* Hence the voltage drop across it also decreases.
* The voltage drop is nothing but voltage at the base with respect to ground. Hence V_{BE} decreases which decrease I_B.

* This behaviour will tend to offset the increase in I_C with Temperature
* We know,

$$I_C = \beta I_B + (1+\beta) I_{CBO}$$

→ In this equation, There is increase in I_{CBO} & decrease in I_B which keeps I_C almost constant.



In This Fig:

* The Thermistor is connected b/w Emitter & Vcc to minimize the increase in I_C due to changes in I_{CO}, β (or) V_{BE} with Temperature.
* I_C increases with Temperature & R_T decreases with increase in Temperature.
* ∴ the current flow through R_E increases, which increase the voltage drop across it.
* The Emitter-Base junction is forward biased.

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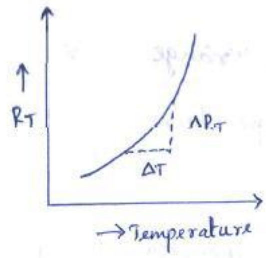
* But due to increase in voltage drop across R_E, emitter is made more positive which decreases the forward bias voltage V_{BE}.
* Hence base current decreases.
* I_c is given by

$$I_c = \beta I_B + (1+\beta) I_{CBO}$$

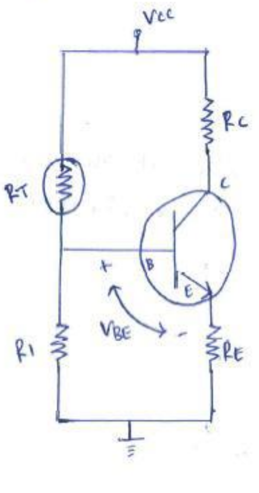
* As I_{CBO} increases with Temperature, I_B decreases & hence I_c remains fairly constant.

3. Sensistor compensation Technique



* This method uses temperature sensitive devices such as sensistor rather than diode or Transistor.
* It has a positive temperature coefficient, its resistance increases exponentially with increase temperature.

* slope of this curve $= \frac{\partial R_T}{\partial T}$
* $\frac{\partial R_T}{\partial T}$ is the temperature coefficient for sensistor & the slope is positive
* So we can say that sensistor have positive temperature coefficient of resistance (PTC)



In this fig:
* R_1 is replaced by sensistor R_T in self bias circuit.
* Now R_T & R_2 are 2 resistors of the potential divider
* As temperature increases, R_T increases which decrease the current flowing through it.
* Hence the current through R_2 decreases which decrease the voltage drop across it.
* Voltage drop across R_2 is the voltage b/w base & ground.
* So V_{BE} decreases which decreases I_B.

* $I_c = \beta I_B + (1+\beta) I_{CBO}$ → When I_{CBO} increases with increase in Temperature, I_B decreases due to reduction in V_{BE}, maintaining I_c fairly constant.