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LINEAR INTEGRATED CIRCUITS

PART-06

Constant Current Biasing Techniques for Differential Amplifiers

DR SATVIR SINGH
DEPARTMENT OF ECE
IKG PUNJAB TECHNICAL UNIVERSITY
KAPURTHALA-144603 (PB) INDIA

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Constant Current Biasing - Outline

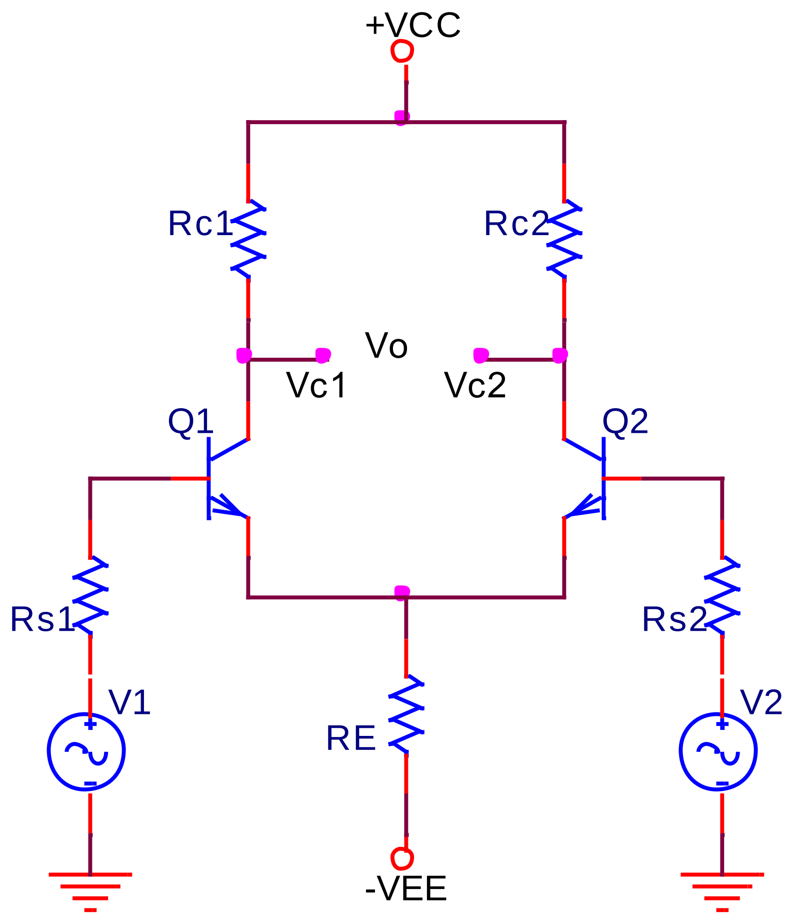
1. Why constant current biasing?
2. Constant current biasing techniques
   - ❑ Simple basing
   - ❑ PN diode based biasing
   - ❑ Zener diode based biasing
   - ❑ Current mirror based biasing
3. Summary

Why Constant Current Biasing?

- Operating point currents in Differential Amplifiers

$$I_{E1} = I_{E2} = \frac{V_{EE} - V_{BE}}{(R_s/\beta + 2R_E)}$$

- Depends upon β that change with transistor.
- Depends upon V_{BE} that change with temperature.
- To remove these dependencies
  - Increase R_E leads to increase in CMRR but reduces I_E
  - Increase I_E, we have to increase V_{EE}
- Alternatively, Constant Current Biasing is used



Refer: Part-03 DC Analysis of BJT Differential Amplifiers

Constant Current Biasing – Simple

Voltage at the base terminal of Q_3 is given as

$$V_{B3} = \frac{-V_{EE}}{R_1 + R_2} R_2$$

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

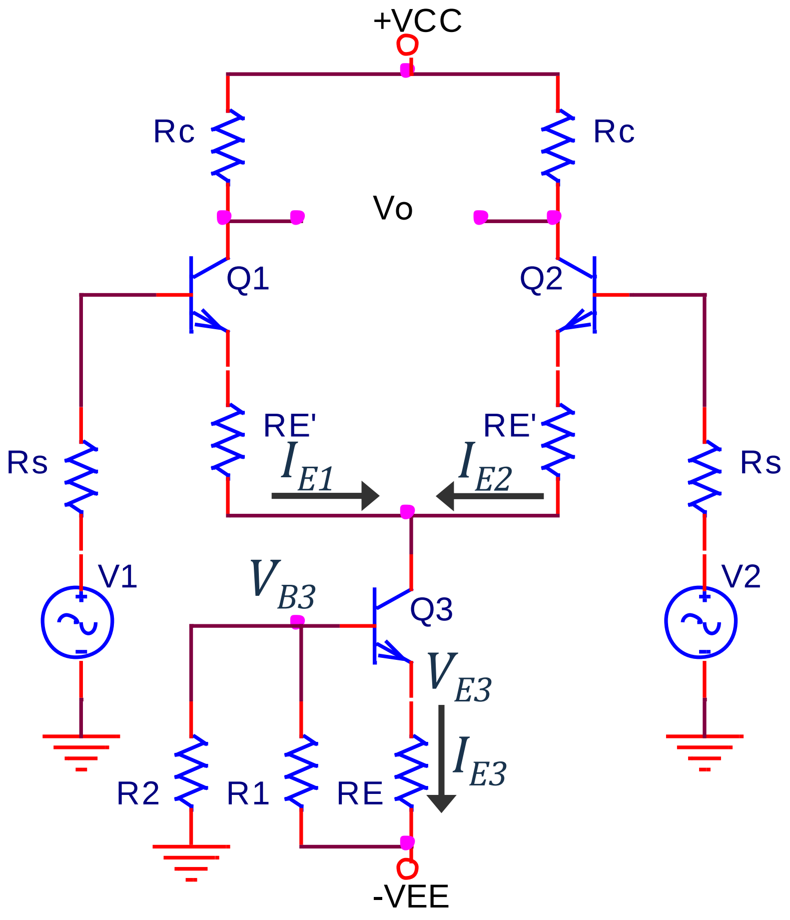
$$V_{E3} = V_{B3} - V_{BE3} = -\frac{V_{EE}}{R_1+R_2} R_2 - V_{BE3} \qquad (1)$$

Current through R_E is

$$I_{E3} = \frac{V_{E3} - (-V_{EE})}{R_E} = \frac{1}{R_E}(V_{EE} + V_{E3})$$

Put V_{E3} from (1)

$$I_{E3} = \frac{1}{R_E}\left(V_{EE} - \frac{R_2}{R_1 + R_2} V_{EE} - V_{BE3}\right) = I_{C3}$$



Constant Current Biasing – Simple

Due to symmetrical circuitry

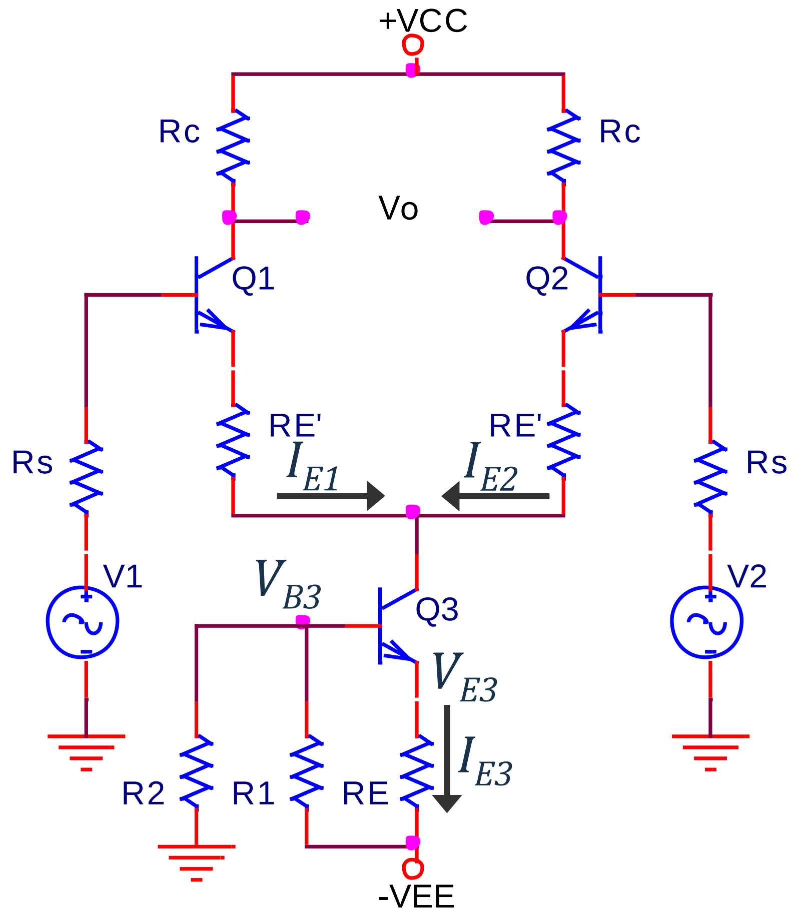
$$I_{E1} = I_{E2} = \frac{I_{C3}}{2}$$

$$I_{E1} = I_{E2} = \frac{1}{2R_E}\left(V_{EE} - \frac{R_2}{R_1 + R_2}V_{EE} - V_{BE3}\right)$$

Hence, currents in Q_1 and Q_2 do not depend on β

However, still dependent upon V_{BE3} whose value decreases @ 2mV/°C.

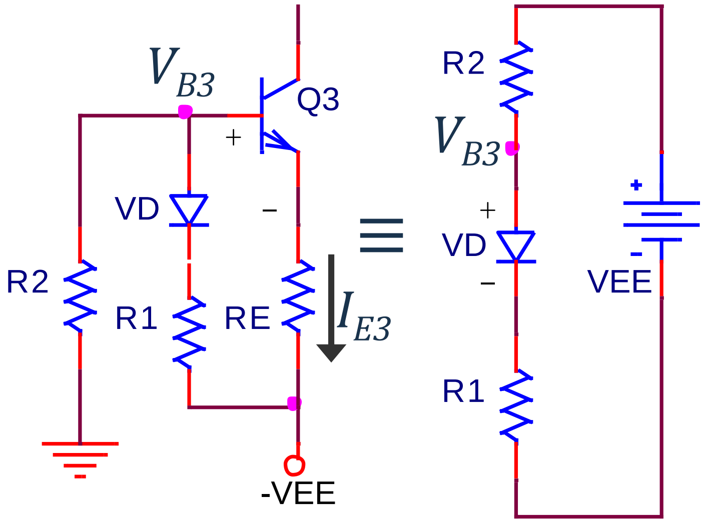
Let's now consider biasing for thermal stability.



Constant Current Biasing - PN Diode

Thermal stability of the circuit can be increased with a diode, if placed in series with R_1.

From base voltage V_{B3} using KVL



$V_{B3} = (V_{EE} - V_D)\frac{R_1}{R_1+R_2} + V_D$ and $V_{B3} = V_{BE3} + I_{E3}R_E$

$$(V_{EE} - V_D)\frac{R_1}{R_1 + R_2} + V_D = V_{BE3} + I_{E3}R_E$$

$$I_{E3} = \frac{1}{R_E}\left(\frac{V_{EE}R_1}{R_1 + R_2} + V_D - \frac{V_D R_1}{R_1 + R_2} - V_{BE3}\right)$$

$$I_{E3} = \frac{1}{R_E}\left(\frac{V_{EE}R_1}{R_1 + R_2} + \frac{V_D R_1 + V_D R_2 - V_D R_1}{R_1 + R_2} - V_{BE3}\right)$$

Constant Current Biasing - PN Diode

After simplification

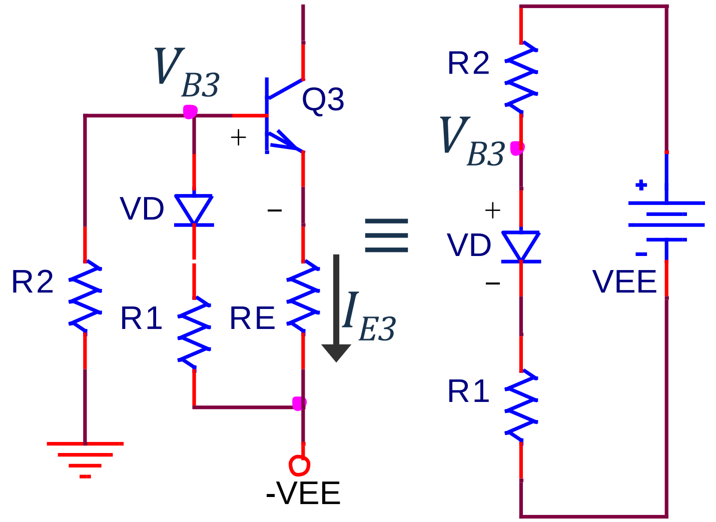
$$I_{E3} = \frac{1}{R_E}\left(\frac{V_{EE}R_1}{R_1 + R_2} + \frac{V_D R_2}{R_1 + R_2} - V_{BE3}\right)$$

Adjust R_1 and R_2 so that

$$V_{BE3} = \frac{V_D R_2}{R_1 + R_2} \qquad (2)$$

$$I_{E3} = \frac{1}{R_E}\frac{V_{EE}R_1}{R_1 + R_2}$$

$$I_{E1} = I_{E2} = \frac{I_{E3}}{2} = \frac{1}{2R_E}\frac{V_{EE}R_1}{R_1 + R_2}$$



The effect of temperature in the form of voltage variation in transistor is cancelled by diode.

Constant Current Biasing - Zener Diode

Zener diodes may be used in place of diodes.

$$V_{B3} = V_Z - V_{EE}$$

$$V_{E3} = V_{B3} - V_{BE3}$$

$$V_{E3} = V_Z - V_{EE} - V_{BE3}$$

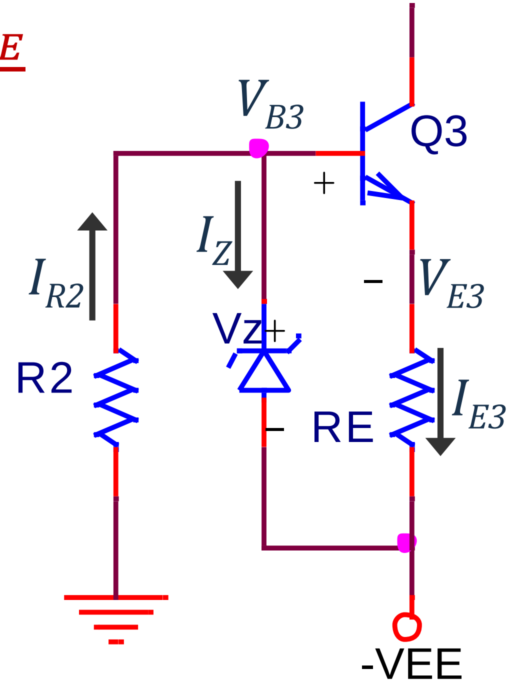
However, $I_{E3} = \frac{V_{E3}+V_{EE}}{R_E}$

$$I_{E3} = \frac{V_Z - V_{EE} - V_{BE3} + V_{EE}}{R_E} = \frac{V_Z - V_{BE3}}{R_E}$$

$$I_{E1} = I_{E2} = \frac{I_{E3}}{2} = \frac{V_Z - V_{BE3}}{2R_E}$$

Resistance R_2 is adjusted make Zener diode conduct in reverse bias, i.e., $I_{R2} = 1.2 I_{Z(min)}$

$$R_2 = \frac{V_{B3}}{I_{R2}} = \frac{V_Z - V_{EE}}{I_{R2}}$$



Constant Current Biasing - Current Mirror

Circuit in which output current is forced to equal input current is called a Current Mirror circuit.

Q_3 and Q_4 are identical, therefore

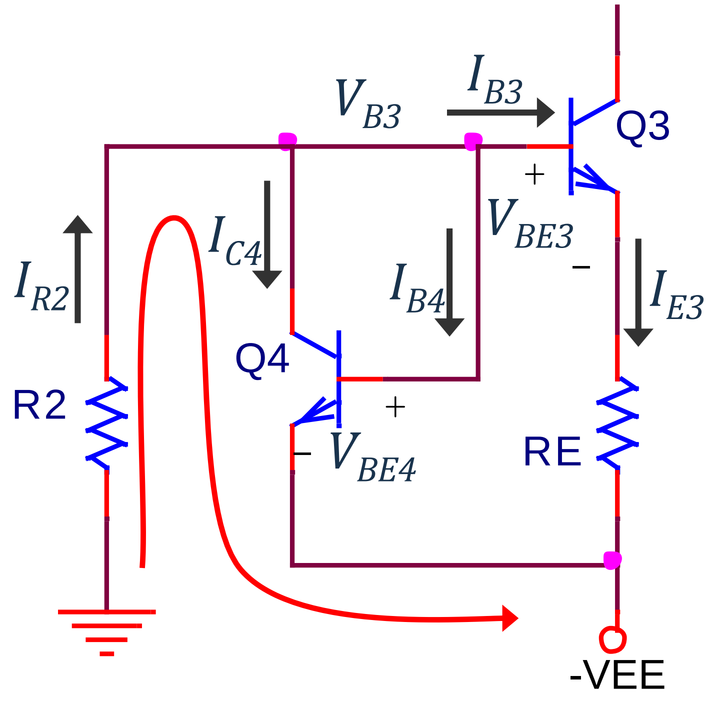
$$I_{B3} = I_{B4}, I_{C3} = I_{C4} \text{ and } V_{BE3} = V_{BE4}$$

Apply KCL at node V_{B3}

$$I_{R2} = I_{C4} + I_{B3} + I_{B4} = I_{C3} + 2I_{B3}$$

$$I_{R2} = I_{C3} + 2\frac{I_{C3}}{\beta} = I_{C3}\left(1 + \frac{2}{\beta}\right) \approx I_{C3}$$

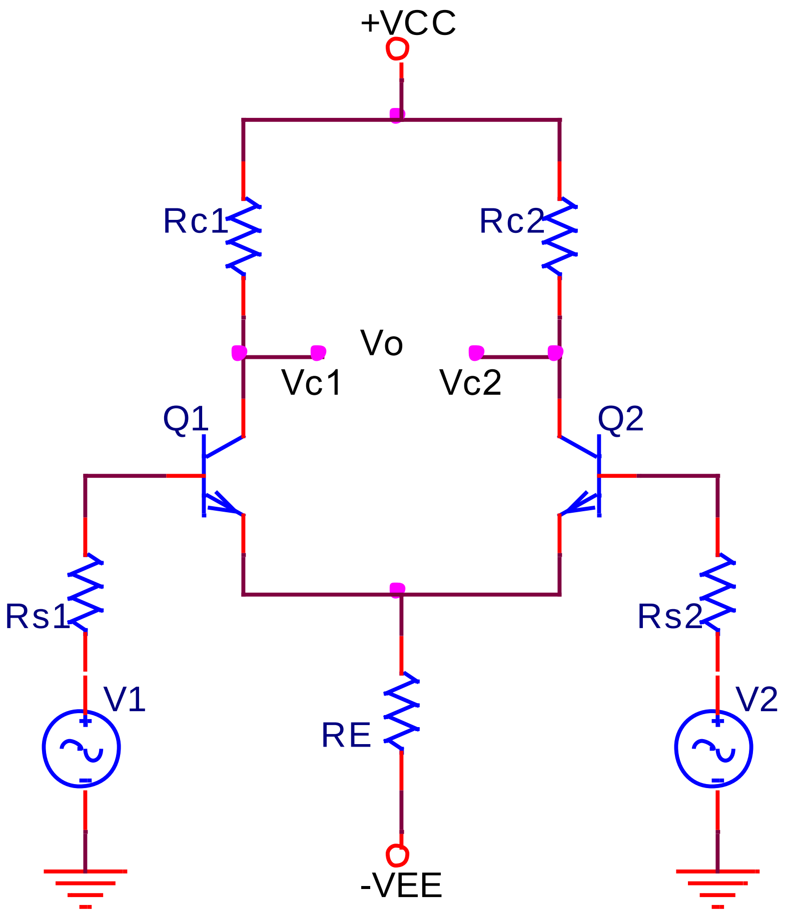
$$I_{R2} = I_{C4} = \frac{V_{BE} - V_{EE}}{R_2} = I_{E3}$$



Summary - Constant Current Biasing

Operating Current **without Constant Current Biasing**

$$I_E = \frac{V_{EE} - V_{BE}}{(R_s/\beta + 2R_E)}$$



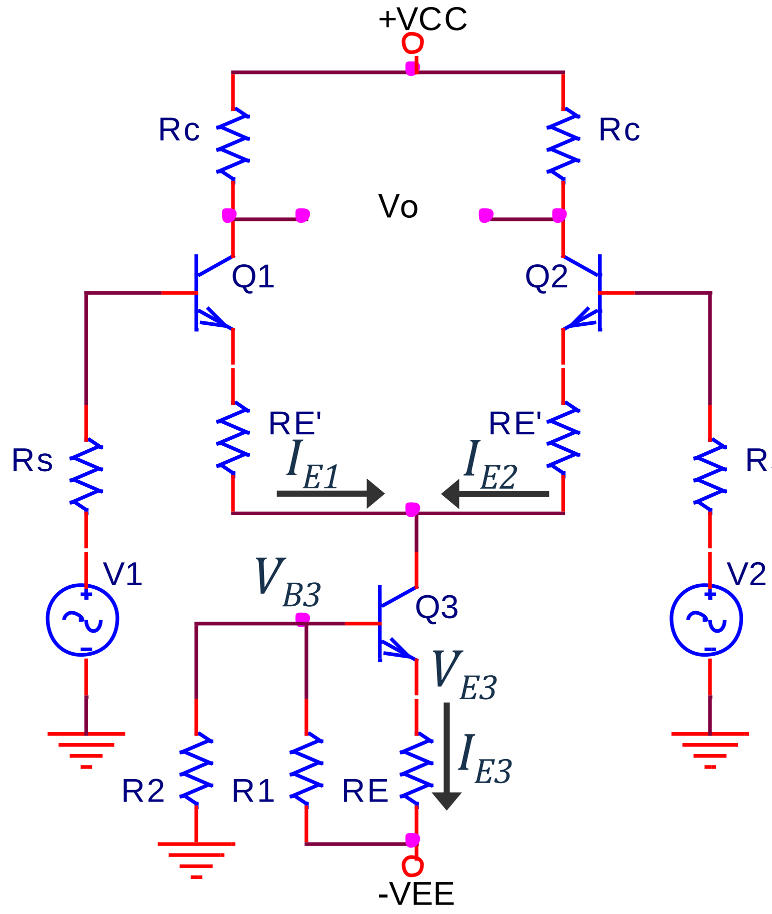
Summary - Constant Current Biasing

Operating Current without Constant Current Biasing

$$I_E = \frac{V_{EE} - V_{BE}}{(R_S/\beta + 2R_E)}$$

(1) **Simple Biasing**

$$I_E = \frac{V_{EE} - \frac{R_2}{R_1 + R_2} V_{EE} - V_{BE3}}{2R_E}$$



Summary - Constant Current Biasing

Operating Current without Constant Current Biasing

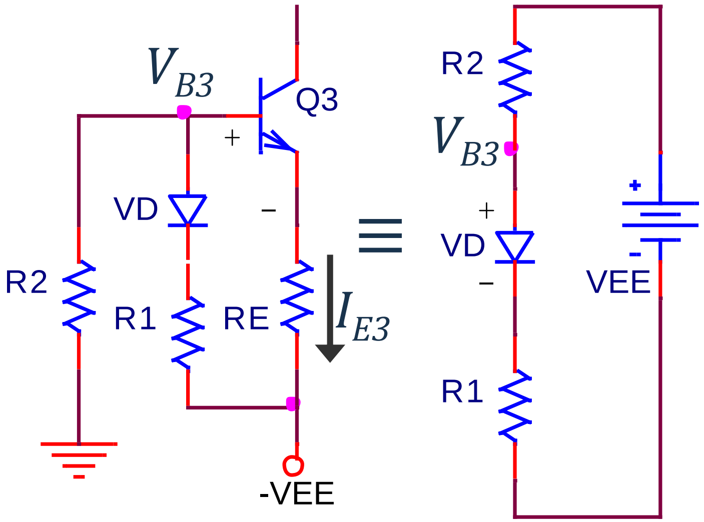
$$I_E = \frac{V_{EE} - V_{BE}}{(R_s/\beta + 2R_E)}$$

(1) Simple Biasing

$$I_E = \frac{V_{EE} - \frac{R_2}{R_1 + R_2} V_{EE} - V_{BE3}}{2R_E}$$

(2) **PN Diode Biasing** $\left(V_{BE3} = \frac{V_D R_2}{R_1 + R_2}\right)$

$$I_E = \frac{1}{2R_E} \frac{V_{EE} R_1}{R_1 + R_2}$$



Summary - Constant Current Biasing

Operating Current without Constant Current Biasing

$$I_E = \frac{V_{EE} - V_{BE}}{(R_S/\beta + 2R_E)}$$

(1) Simple Biasing

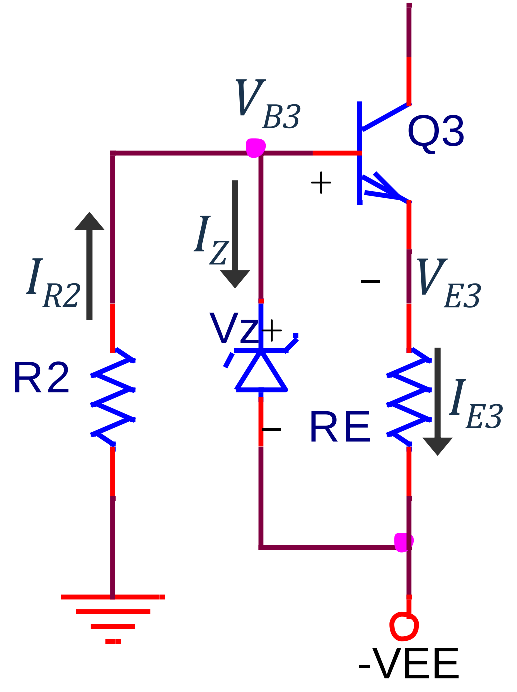
$$I_E = \frac{V_{EE} - \frac{R_2}{R_1 + R_2} V_{EE} - V_{BE3}}{2R_E}$$

(2) PN Diode Biasing

$$I_E = \frac{1}{2R_E} \frac{V_{EE} R_1}{R_1 + R_2}$$

(3) **Zener Diode Biasing**

$$I_E = \frac{V_Z - V_{BE3}}{2R_E}$$



Summary - Constant Current Biasing

Operating Current without Constant Current Biasing

$$I_E = \frac{V_{EE} - V_{BE}}{(R_s/\beta + 2R_E)}$$

(1) Simple Biasing

$$I_E = \frac{V_{EE} - \frac{R_2}{R_1 + R_2} V_{EE} - V_{BE3}}{2R_E}$$

(2) PN Diode Biasing

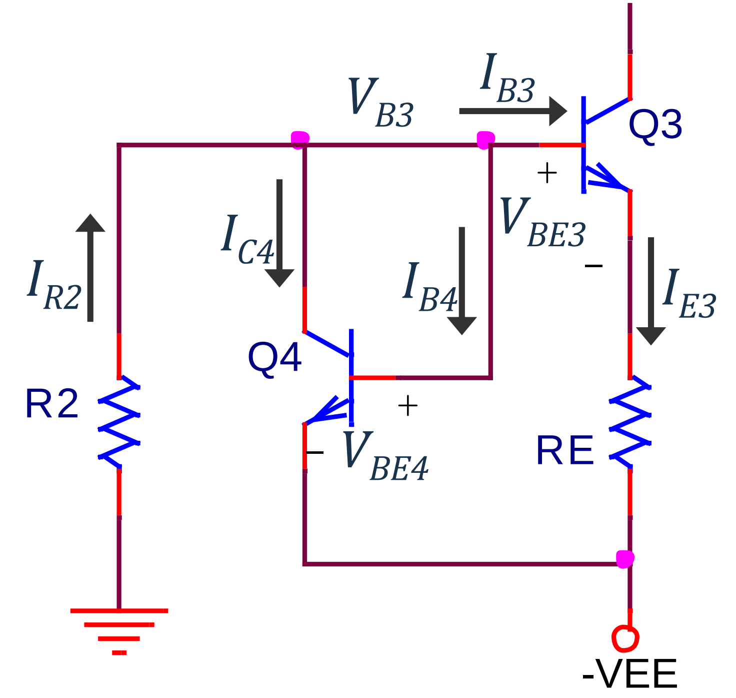
$$I_E = \frac{1}{2R_E} \frac{V_{EE} R_1}{R_1 + R_2}$$

(3) Zener Diode Biasing

$$I_E = \frac{V_Z - V_{BE3}}{2R_E}$$

(4) **Current Mirror Biasing**

$$I_E = \frac{V_{BE} - V_{EE}}{2R_2}$$



Thank You

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