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LINEAR INTEGRATED CIRCUITS

PART-05

Advantages of Swamping Resistors in Differential Amplifier

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Differential Amplifier

- Differential Voltage Gain

$$A_d = \frac{R_C}{r_e}$$

- Input Resistance

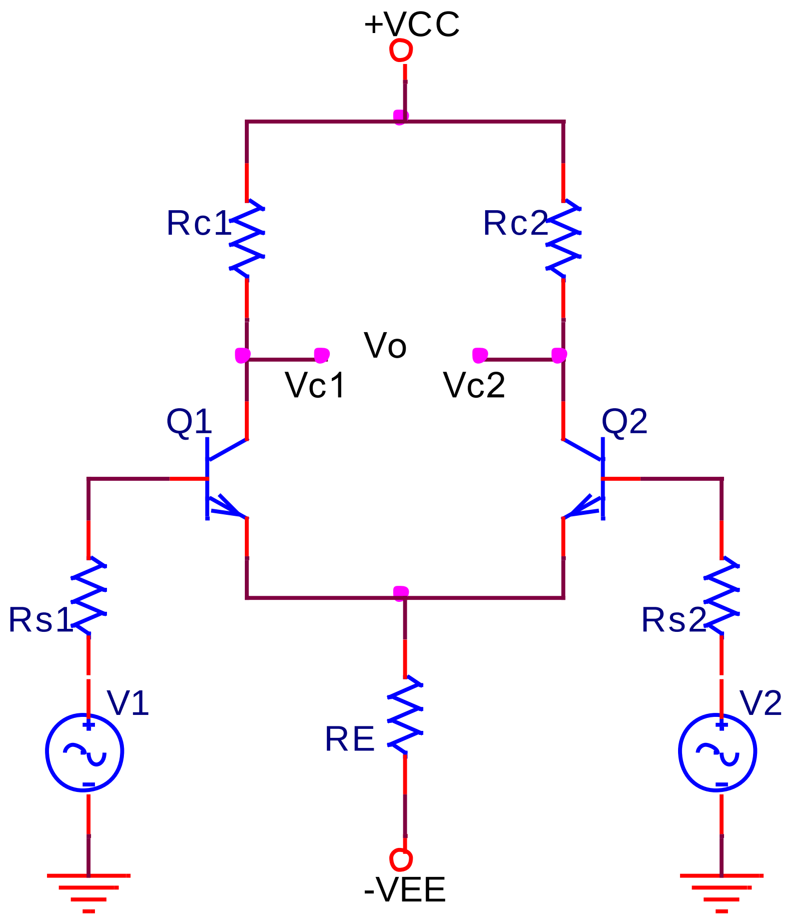
$$R_i = 2\beta r_e$$

- Further, Dynamic Emitter Resistance r_e is

$$r_e = \frac{\eta V_T}{I_E}$$

$$V_T = kT \approx 25mV \text{ at room temperature}$$

- Consequently, A_d and R_i depend upon temperature



Refer: Part-04 AC Analysis of BJT Differential Amplifiers

Effect of Swamping Resistance

To reduce the effect of temperature (r_e), an external resistance R_E' is placed in series with emitter terminal

DC Analysis ($V_1 = V_2 = 0$)

KVL in input loop

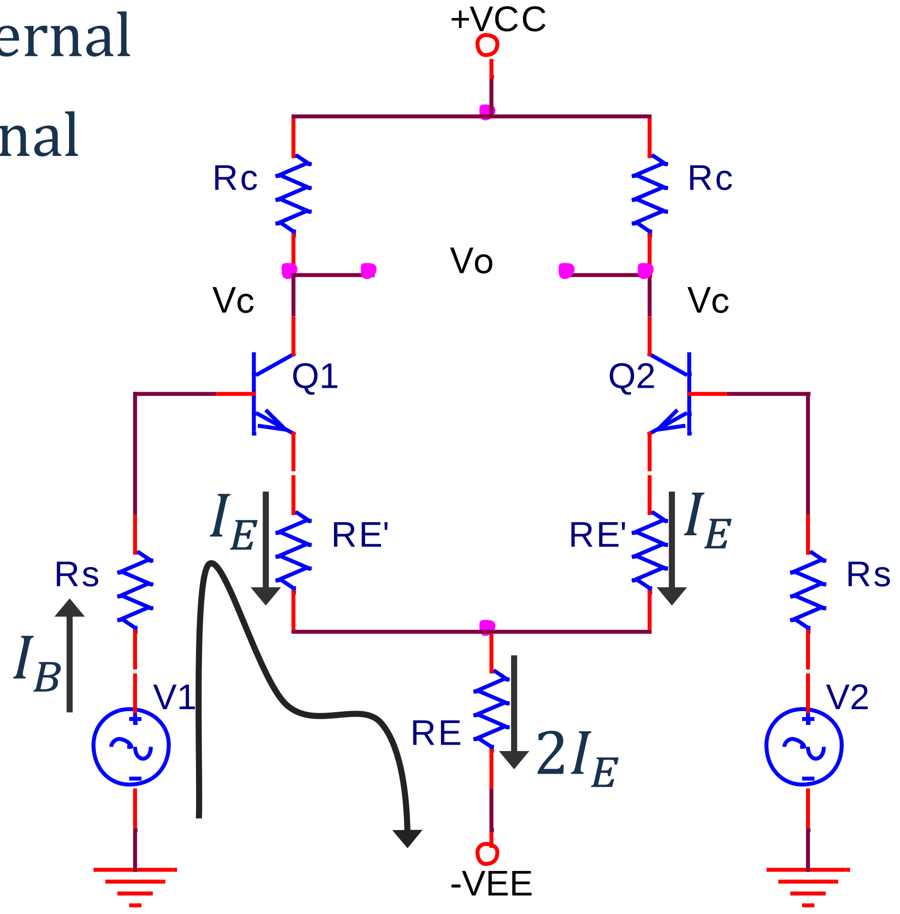
$$I_B R_s + V_{BE} + I_E R_E' + 2I_E R_E = V_{EE}$$

Replace $I_B = I_E/\beta$

$$R_s\, I_E/\beta + I_E R_E' + 2I_E R_E = V_{EE} - V_{BE}$$

Simplification gives

$$I_E = \frac{V_{EE} - V_{BE}}{R_E' + 2R_E + R_s/\beta} \approx \frac{V_{EE} - V_{BE}}{R_E' + 2R_E} \approx I_C$$



Refer: Part-03 DC Analysis of BJT Differential Amplifiers

Effect of Swamping Resistance

Collector to Emitter voltage is given as

$$V_{CE} = V_C - V_E \qquad (1)$$

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

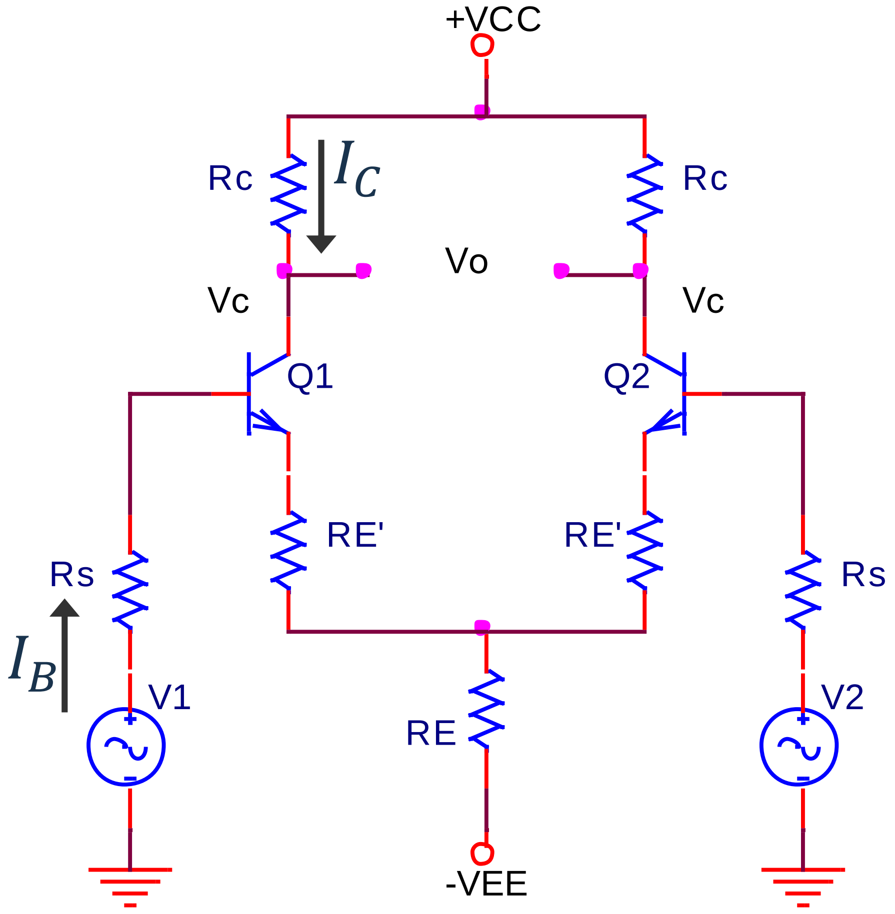
Further, $V_{BE} = V_B - V_E$ but $V_B = -I_B R_s \cong 0$

$$V_E \cong -V_{BE}$$

Substitute V_C and V_E in (1)

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

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



Refer: Part-03 DC Analysis of BJT Differential Amplifiers

Effect of Swamping Resistance

AC analysis ($V_{CC} = V_{EE} = 0$)

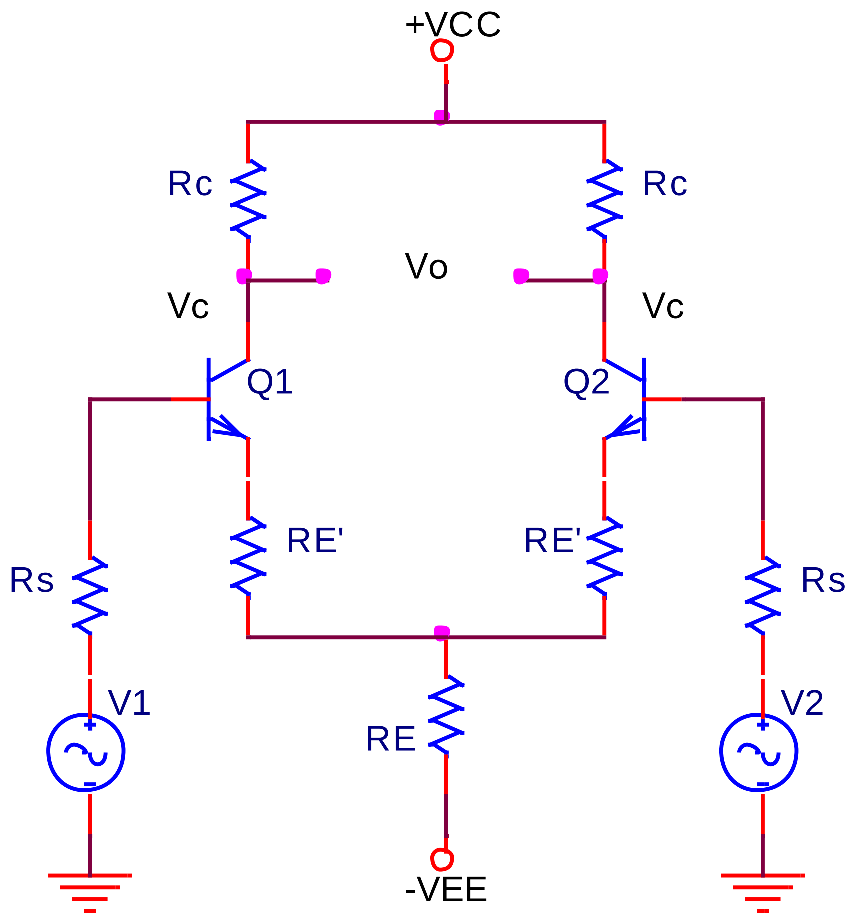
Differential Voltage Gain is given

$$A_d = \frac{R_C}{r_e + R_E'} \approx \frac{R_C}{R_E'}$$

Similarly Input Resistance is given as

$$R_{i1} = R_{i2} \approx 2\beta(r_e + R_E') \approx 2\beta R_E'$$

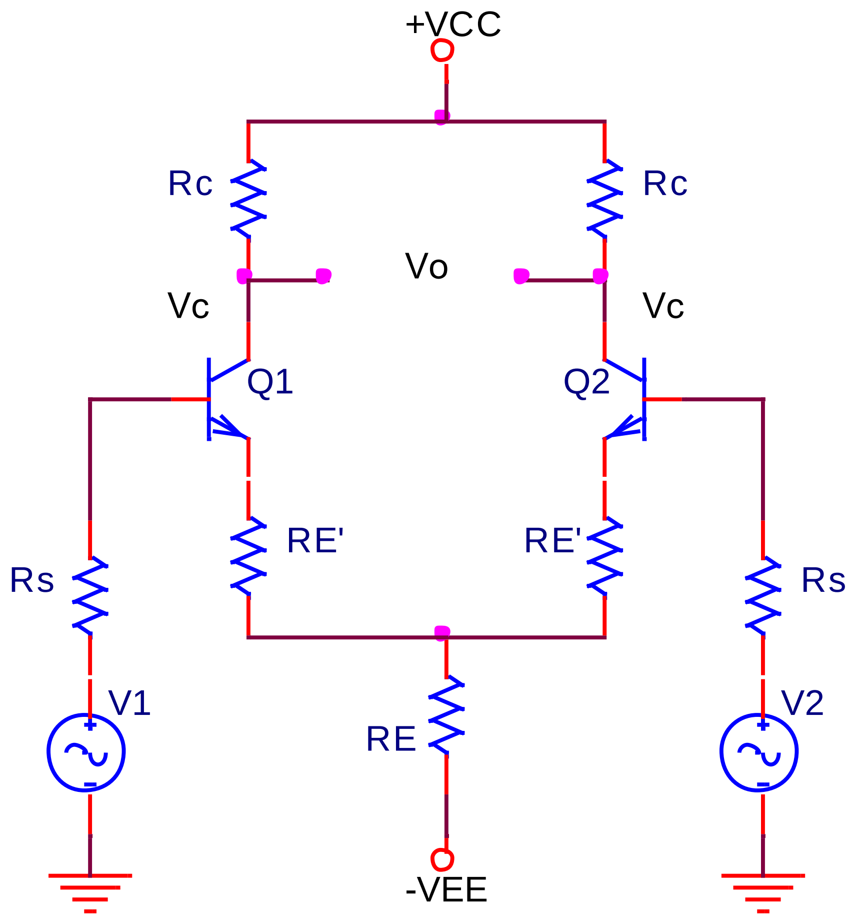
Hence, Swamping Resistance R_E' reduces the dependency of Voltage Gain and Input Resistances on r_e (temperature as well).



Refer: Part-04 AC Analysis of BJT Differential Amplifiers

Numerical Problem – Statement

Let's consider a Dual Input Balanced Output Differential circuit having $R_C = 2.2k\Omega, R_E = 4.7k\Omega, R_S = 50\Omega, V_{CC} = +10V, V_{EE} = -10V,$ $\beta = 100$ and $V_{BE} = 0.7V$. Here Swamping Resistance is $R_E' = 1k\Omega$ ($r_e \approx 25.3\Omega$).



Determine

(1) Q-point I_{CQ} & V_{CEQ}

(2) Differential Voltage Gain A_d

(3) Input Resistances R_i

(4) Output Resistance R_o

Numerical Problem – Solution

(1) Operating Point Current is given as

$$I_{CEQ} = \frac{V_{EE} - V_{BE}}{R'_E + 2R_E + R_s/\beta}$$

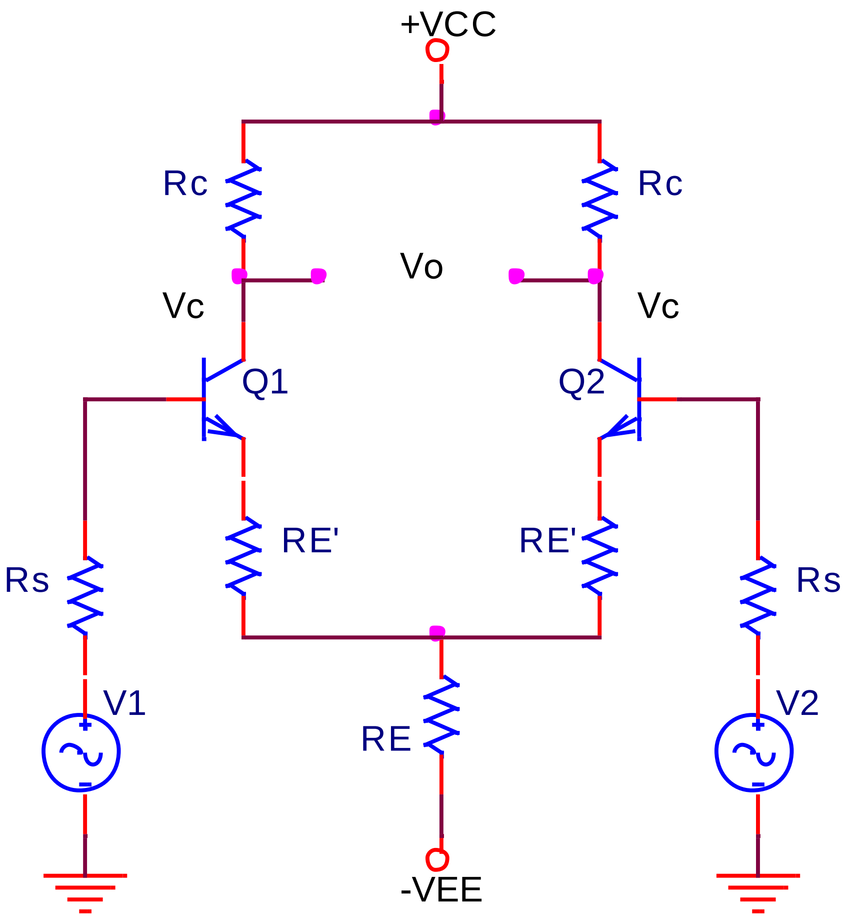
$$I_{CEQ} = \frac{10 - 0.7}{1k + 2 * 4.7k + 50/100} = \frac{9.3}{1k + 9.4k + 0.5}$$

$$I_{CEQ} = \mathbf{0.894mA}$$

Operating Point Voltage is give by

$$V_{CEQ} = V_{CC} - I_C R_C + V_{BE}$$

$$V_{CEQ} = 10 - 0.894m * 2.2k + 0.7 = \mathbf{7.33V}$$



Numerical Problem – Solution

(2) Differential Voltage Gain is given

$$A_d = \frac{R_C}{R'_E}$$

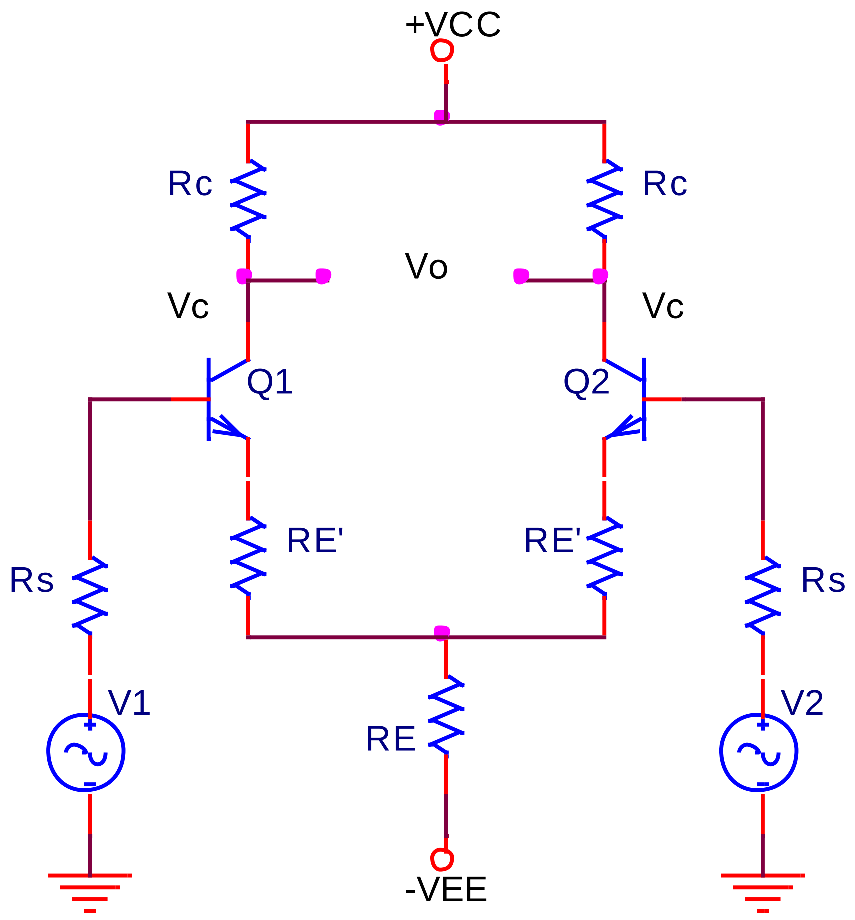
$$A_d = \frac{2.2k}{1k} = \mathbf{2.2}$$

(3) Input resistances are

$$R_i = 2\beta R'_E = 2 * 100 * 1k = \mathbf{200k\Omega}$$

(4) Output resistances are

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



Thank You

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