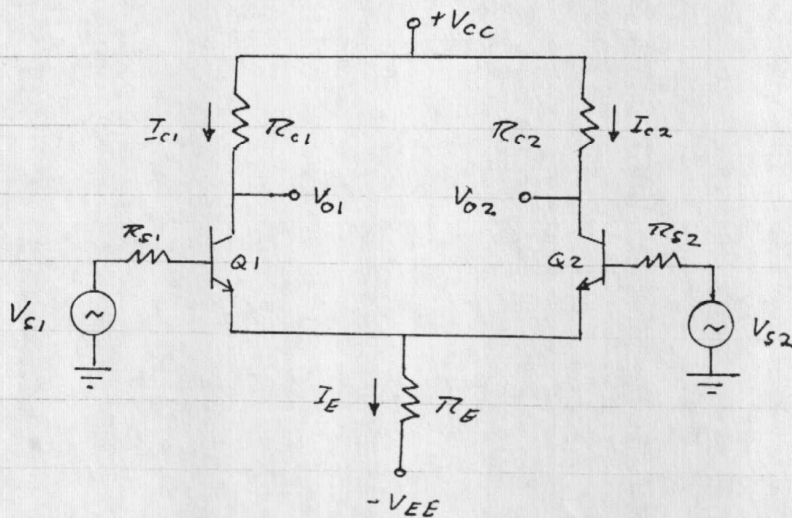


IV Operational Amplifier Circuits

4.1 The Differential Amplifier

Basic Configuration



assumption:

Q_1 and Q_2 are
a matched pair

Def Common Mode input voltage:

$$\left| V_{cm} = \frac{V_{s1} + V_{s2}}{2} \right|$$

Common Mode voltage gain:

$$\left| A_{cm} = \frac{V_o}{V_{cm}} = \frac{V_o}{V_{s1}} \right|_{V_{s2}=V_{s1}}$$

where: $V_o = V_{02}$ (single ended output)

$V_o = V_{02} - V_{01}$ (differential output)

IV-2

Differential Mode input voltage

$$V_d = (V_{s1} - V_{s2})$$

Differential Mode voltage gain:

$$A_d = \frac{V_o}{V_d} = \frac{V_o}{V_{s1}} \bigg|_{V_{s2}=0}$$

Differential Mode input resistance:

$$R_d = \frac{V_d}{(i_{s1} - i_{s2})} = \frac{V_{s1}}{i_{s1}} \bigg|_{V_{s2}=0}$$

4.1.1 DC Considerations

$$I_{C1} = I_{C2} = \frac{1}{2} I_E$$

$$I_E = \frac{(V_{EE} + V_{CM} - V_{BE})}{\left(\frac{R_E}{2} + R_E\right)} \approx \frac{(V_{EE} + V_{CM} - V_{BE})}{R_E}$$

assumption:

both Transistors are
operated in forward
active region!

Thus:

$$\begin{aligned} I_{C1} = I_{C2} &\approx \frac{(V_{EE} + V_{CM} - V_{BE})}{2R_E} \\ V_{CE1} = V_{CE2} &\approx (V_{CC} + V_{EE}) - (V_{EE} + V_{CM} - V_{BE}) \left(1 + \frac{R_C}{2R_E}\right) \end{aligned}$$

Note: $V_{E1} = V_{E2} = V_{CM} - V_{BE}$