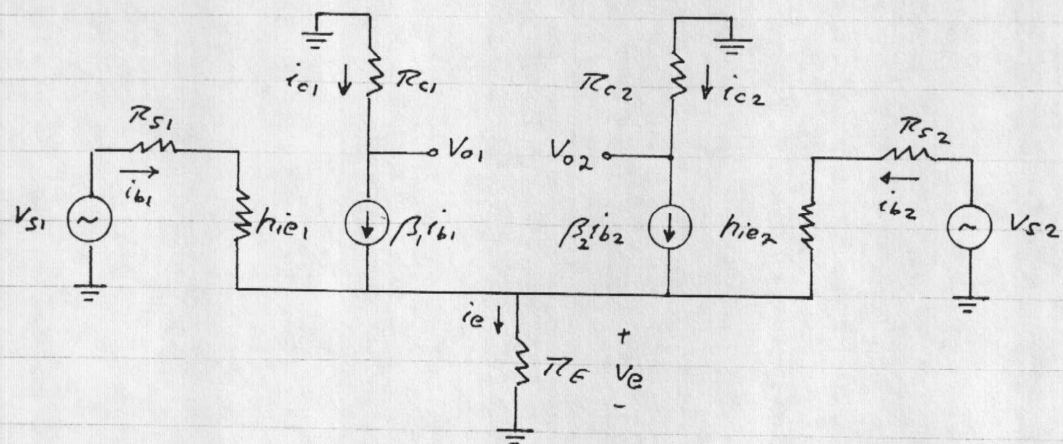
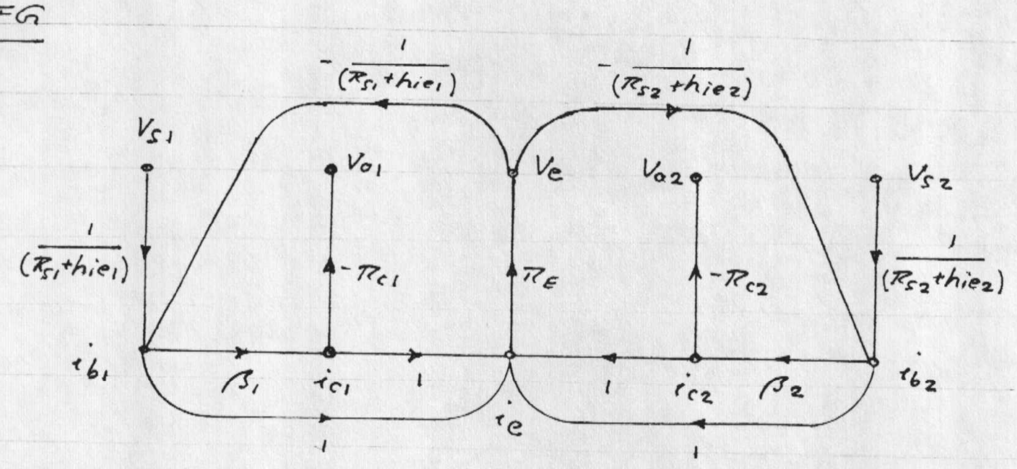
4.1.2 AC Considerations

linear equivalent circuit (h-Parameter model)



SFG



$$\Delta = 1 + (1+\beta_1)\frac{R_E}{(R_{S1}+hie_1)} + (1+\beta_2)\frac{R_E}{(R_{S2}+hie_2)}$$

If Transistors are matched then

$$\Delta = 1 + 2(1+\beta)\frac{R_E}{(R_S+hie)}$$

a) <u>Common Mode voltage gain:</u> (single-ended)

$$A_{cm} = \frac{V_o}{V_{cm}} = \frac{V_o}{V_{s1}}\bigg|_{V_{s2}=V_{s1}} \qquad \text{where } \underline{V_o = V_{o2}}$$

<u>Thus:</u>

$$A_{cm} = -\frac{\beta_2 R_{c2}}{(R_{s2}+h_{ie2})}\left[1+\frac{(1+\beta_1)R_E}{(R_{s1}+h_{ie1})}-\frac{((1+\beta_1)R_E}{(R_{s1}+h_{ie1})}\right]\frac{1}{\Delta}$$

If transistors are matched and $R_{s1}=R_{s2}=R_s$, $R_{c1}=R_{c2}=R_c$ we can rewrite the common mode voltage gain as

$$\left\| A_{cm} = -\frac{\beta R_c}{(R_s+h_{ie}+2[1+\beta]R_E)} \cong -\frac{1}{2}\,\frac{R_c}{(R_E+\frac{1}{2}[\frac{R_s}{\beta}+h_{ib}])} \right\|$$

b) <u>Differential Mode voltage gain:</u> (single-ended)

$$A_d = \frac{V_o}{V_d} = \frac{V_o}{V_{s1}}\bigg|_{V_{s2}=0} \qquad \text{where } \underline{V_o = V_{o2}}$$

<u>Thus:</u>

$$A_d = \frac{\beta_2 R_{c2}}{(R_{s2}+h_{ie2})}\,\frac{(1+\beta_1)R_E}{(R_{s1}+h_{ie1})}\,\frac{1}{\Delta}$$

If both branches of the diff. amplifier are identical we obtain:

$$\left\| A_d = \frac{\beta R_c}{(R_s+h_{ie})}\,\frac{(1+\beta)R_E}{[R_s+h_{ie}+2(1+\beta)R_E]} \cong \frac{1}{2}\,\frac{R_c}{(\frac{R_s}{\beta}+h_{ib})}\,\frac{R_E}{(R_E+\frac{1}{2}[\frac{R_s}{\beta}+h_{ib}])} \right\|$$

<u>Def</u> Common Mode Rejection Ratio

$$\left| CMRR = \frac{|A_d|}{|A_{cm}|} \right|$$