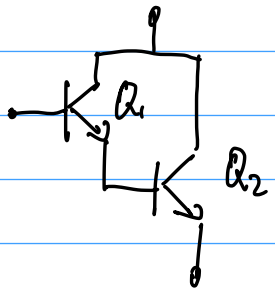
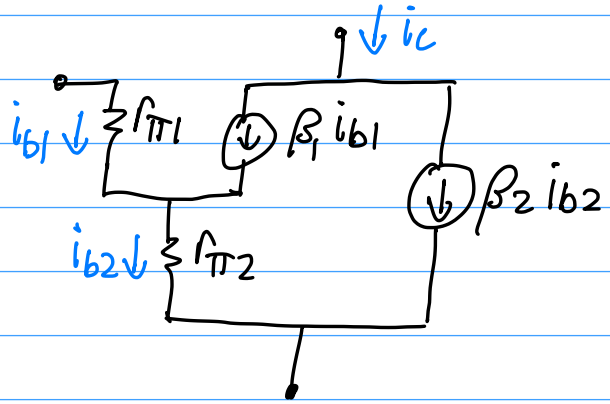
1.



Darlington pair



From the small signal model:

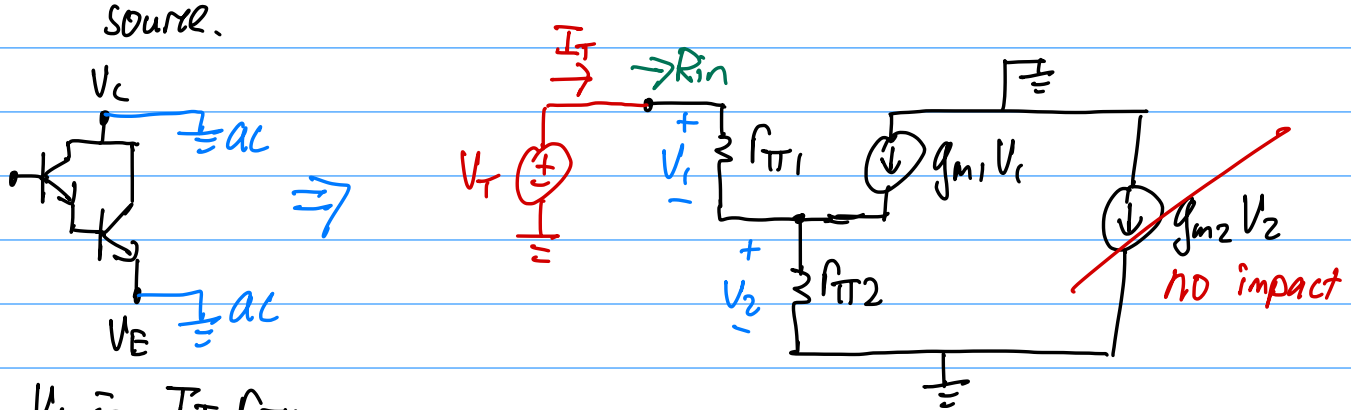
$$i_{b2} = i_{b1} + \beta_1 i_{b1} = (1+\beta_1) i_{b1}$$

$$i_c = \beta_1 i_{b1} + \beta_2 i_{b2}$$

$$= \beta_1 i_{b1} + \beta_2 (1+\beta_1) i_{b1}$$

$$\text{Current gain} = \frac{i_c}{i_{b1}} = \beta_1 + \beta_2 + \beta_1\beta_2.$$

2. Set all independent sources to 0 & connect a test source.



$$V_1 = I_T r_{\pi 1}$$

$$V_2 = (I_T + g_{m1} V_1) r_{\pi 2} = (I_T + g_{m1} I_T r_{\pi 1}) r_{\pi 2}$$

$$V_T = V_1 + V_2 = I_T r_{\pi 1} + I_T r_{\pi 2} + I_T g_{m1} r_{\pi 1} r_{\pi 2}$$

$$\therefore R_{in} = \frac{V_T}{I_T} = r_{\pi 1} + r_{\pi 2} + g_{m1} r_{\pi 1} r_{\pi 2}.$$

Subst. $r_{\pi 1} = \frac{\beta_1}{g_{m1}}$ $\therefore R_{in} = r_{\pi 1} + r_{\pi 2} + \beta_1 r_{\pi 2}.$

$$= r_{\pi 1} + (1+\beta_1) r_{\pi 2}.$$