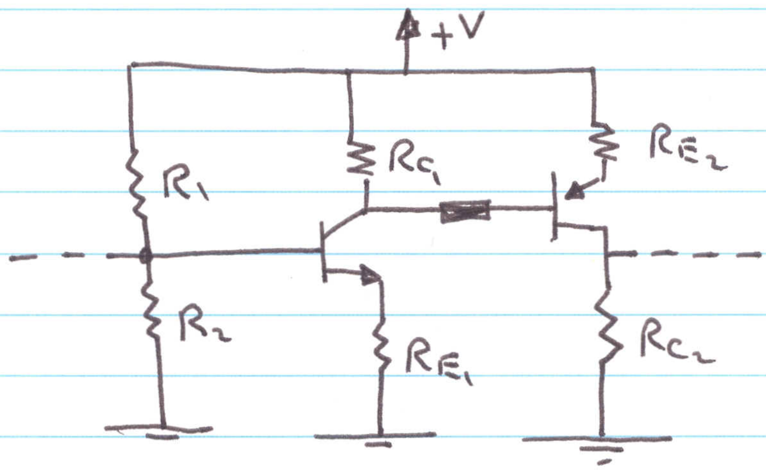
2) Direct - coupled multistage Amplifier



- Used in differential and operational amplifiers
- Used in low and high frequency applications

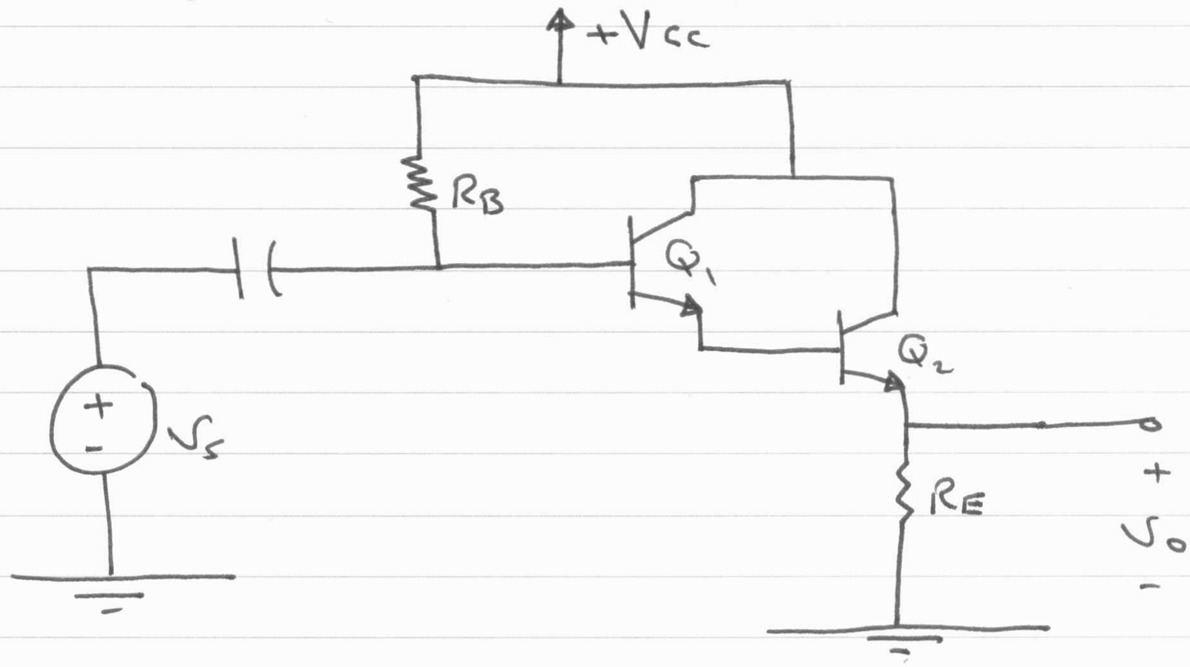
Disadvantages

Any change in the dc voltage at the output of one stage produce an identical change in dc voltage at the input to the next stage

* we must use RE

* we must use alternating transistor types (npn, pnp)

Darlington Compound Configuration



Dc Analysis

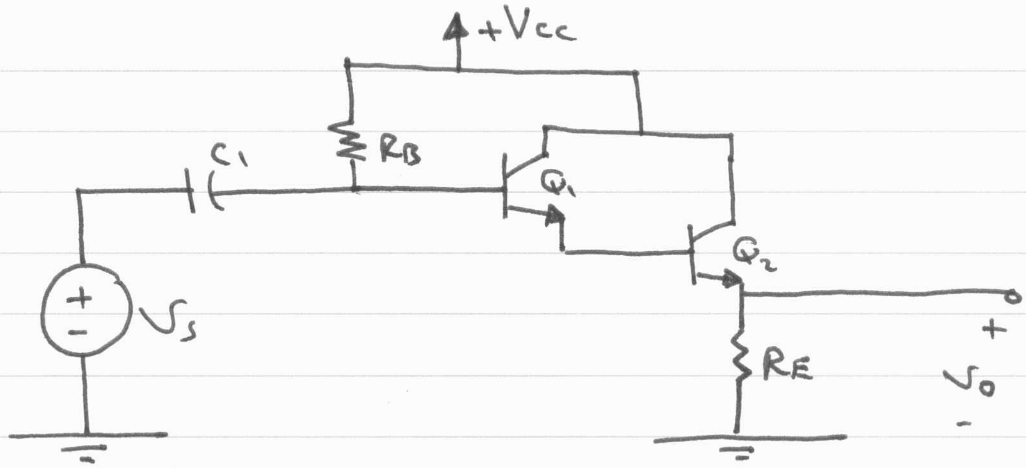
$$V_{CC} = R_B I_{B1} + V_{BE1} + V_{BE2} + R_E I_{E2}$$

$$I_{E2} = (\beta_2 + 1) I_{B2}$$

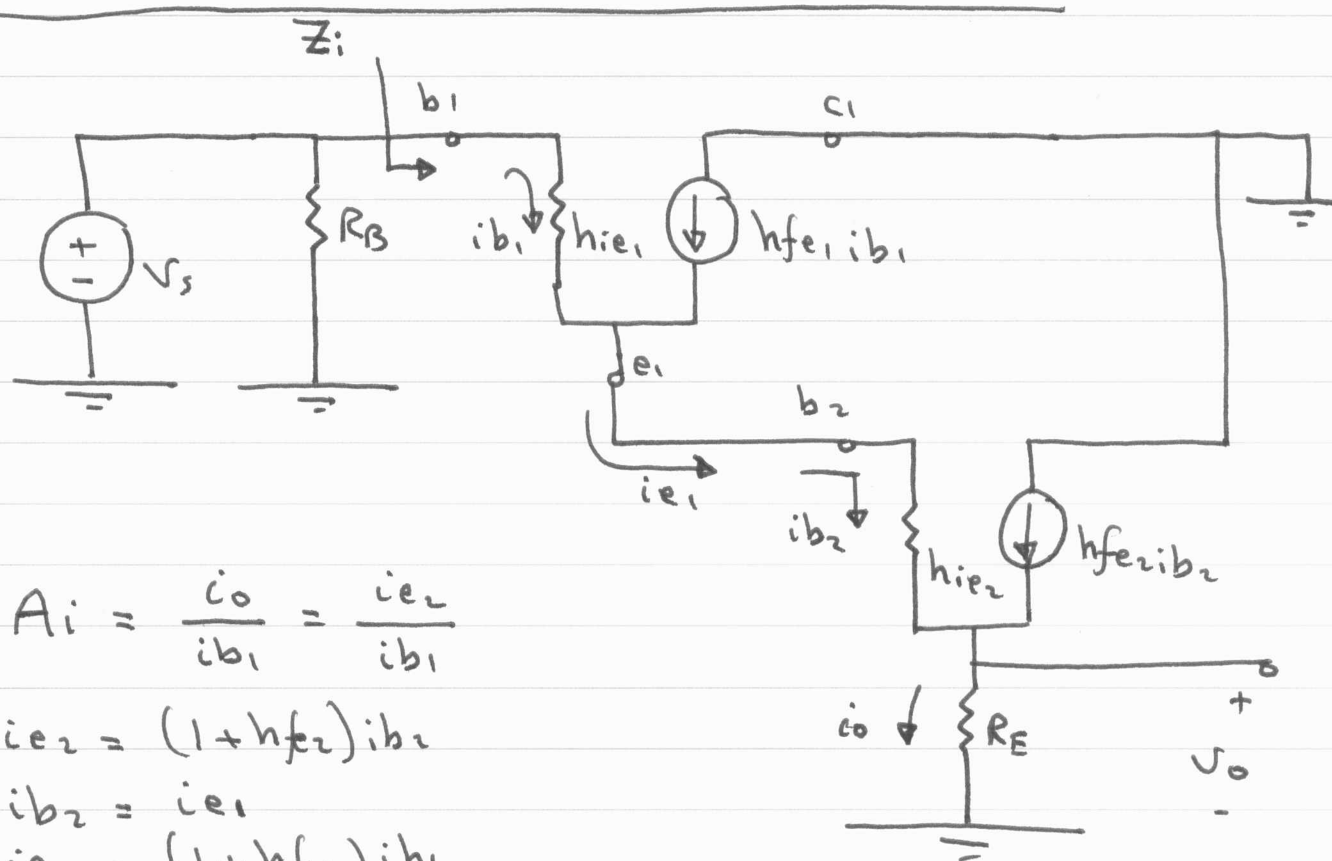
$$I_{B2} = I_{E1}$$

$$I_{E1} = (\beta_1 + 1) I_{B1}$$

$$\therefore \quad I_{E2} = (\beta_2 + 1)(\beta_1 + 1) I_{B1}$$



Ac small signal equivalent circuit



- $A_i = \dfrac{i_o}{i_{b1}} = \dfrac{i_{e2}}{i_{b1}}$

$i_{e2} = (1+h_{fe2})i_{b2}$

$i_{b2} = i_{e1}$

$i_{e1} = (1+h_{fe1})i_{b1}$

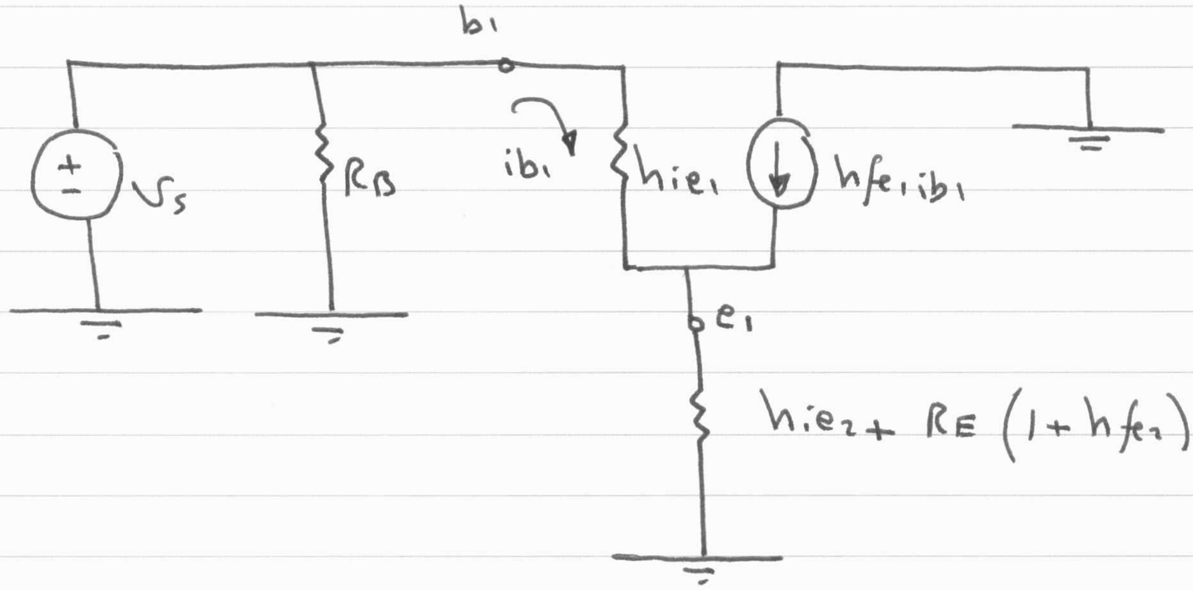
$\therefore A_i = \dfrac{i_o}{i_{b1}} = (1+h_{fe2})(1+h_{fe1})$

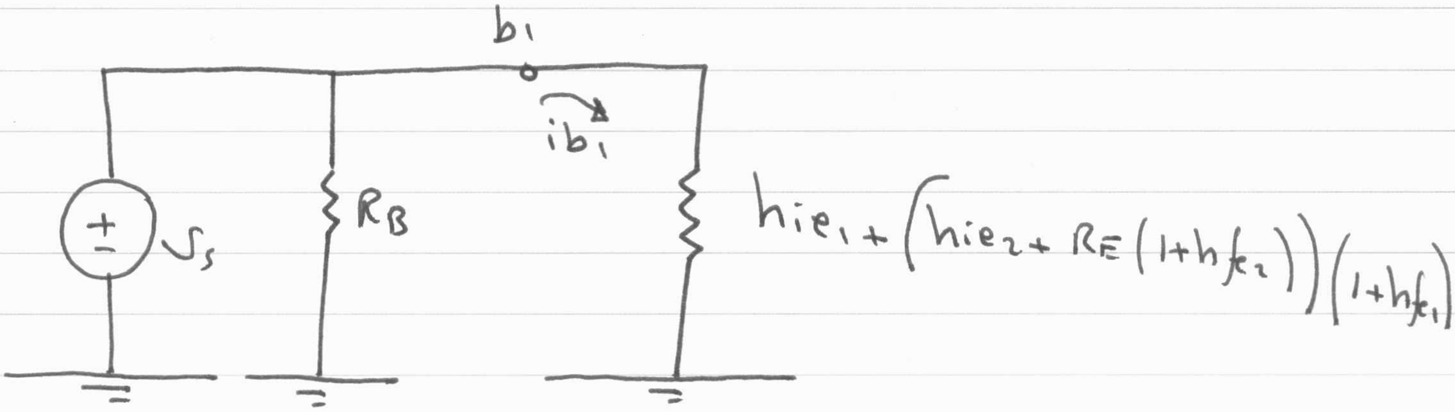
- $A_v = \dfrac{v_o}{v_s}$

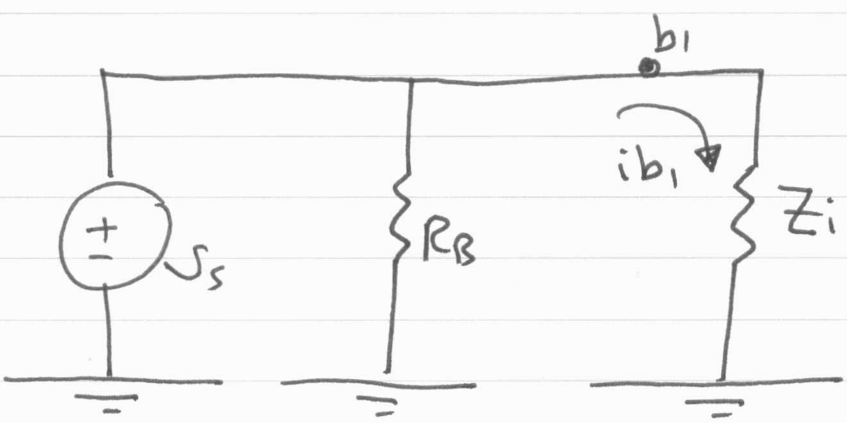
$v_o = R_E i_o$

$i_o = (1+h_{fe2})(1+h_{fe1})\, i_{b1}$

To find i_{b1} ⟶ $base_1$ equivalent circuit







$$i_{b1} = \frac{v_s}{Z_i}$$

$$Z_i = h_{ie1} + \left[h_{ie2} + R_E (1 + h_{fe2}) \right] \left[1 + h_{fe1} \right]$$

$$\therefore A_v = \frac{R_E(1+h_{fe2})(1+h_{fe1})}{h_{ie1} + (R_E(1+h_{fe2}) + h_{ie2})(1+h_{fe1})} < 1$$

- To find Z_o, set $V_s = 0$

$$Z_o = \frac{\frac{h_{ie1}}{h_{fe1}+1} + h_{ie2}}{h_{fe2}+1} \parallel R_E$$

$\therefore$ $A_i > 1$

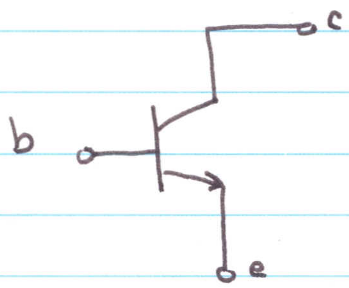
$A_v < 1$

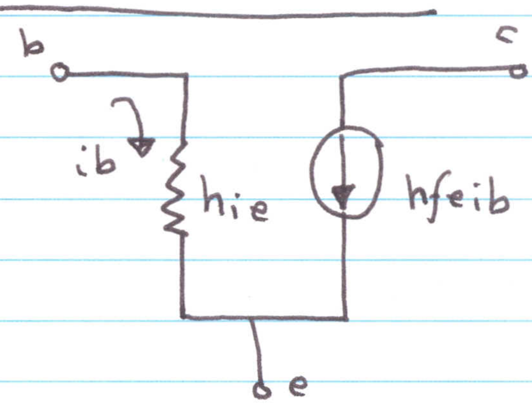
Z_i very very Large

Z_o very very small

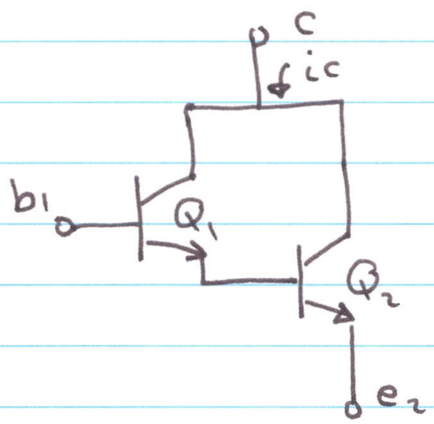
modified Buffer

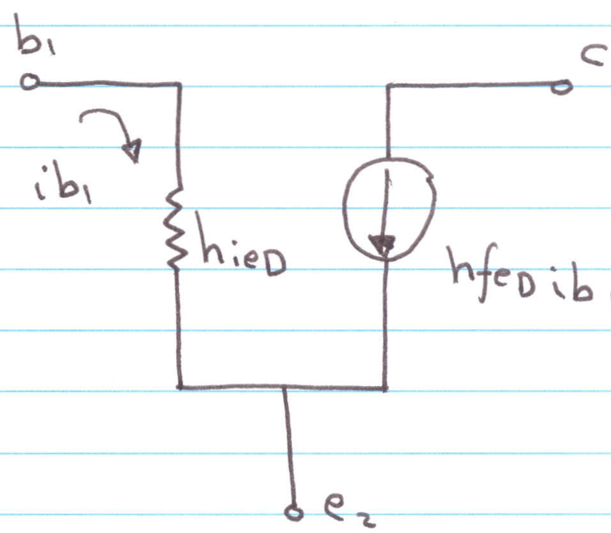
Ac small signal equivalent circuit of the BJT





Ac small signal equivalent circuit of the Darlington :





$$h_{ieD} = 2h_{ie1}$$

$$h_{feD} \equiv h_{fe1} \cdot h_{fe2}$$

$$h_{feD} = \frac{i_c}{i_{b1}}$$

$h_{ieD} = Z_i$ with $R_E = 0$

$$h_{feD} = \frac{i_c}{i_{b1}}$$

$$i_c = i_{c1} + i_{c2}$$

$$i_c = h_{fe1} i_{b1} + h_{fe2} i_{b2}$$

$$i_c = h_{fe1} i_{b1} + h_{fe2} i_{e1}$$

$$i_c = h_{fe1} i_{b1} + h_{fe2} (1 + h_{fe1}) i_{b1}$$

$$i_c = \left[h_{fe1} + h_{fe2} + h_{fe2} h_{fe1} \right] i_{b1}$$

$$\therefore h_{feD} = h_{fe1} + h_{fe2} + h_{fe1} h_{fe2}$$

$$\therefore h_{feD} \approx h_{fe1} h_{fe2}$$

$$h_{ieD} = Z_i \Big|_{R_E = 0}$$

$$Z_i = h_{ie1} + \left(h_{ie2} + R_E (1 + h_{fe2}) \right) (1 + h_{fe1})$$

$$\therefore h_{ieD} = h_{ie1} + (1 + h_{fe1}) h_{ie2}$$

$$= h_{ie1} + (1 + h_{fe1}) \frac{(1 + h_{fe2}) V_T}{I_{E2}}$$

$$= h_{ie1} + (1 + h_{fe1}) \frac{(1 + h_{fe2}) V_T}{(1 + h_{fe2}) I_{E1}}$$

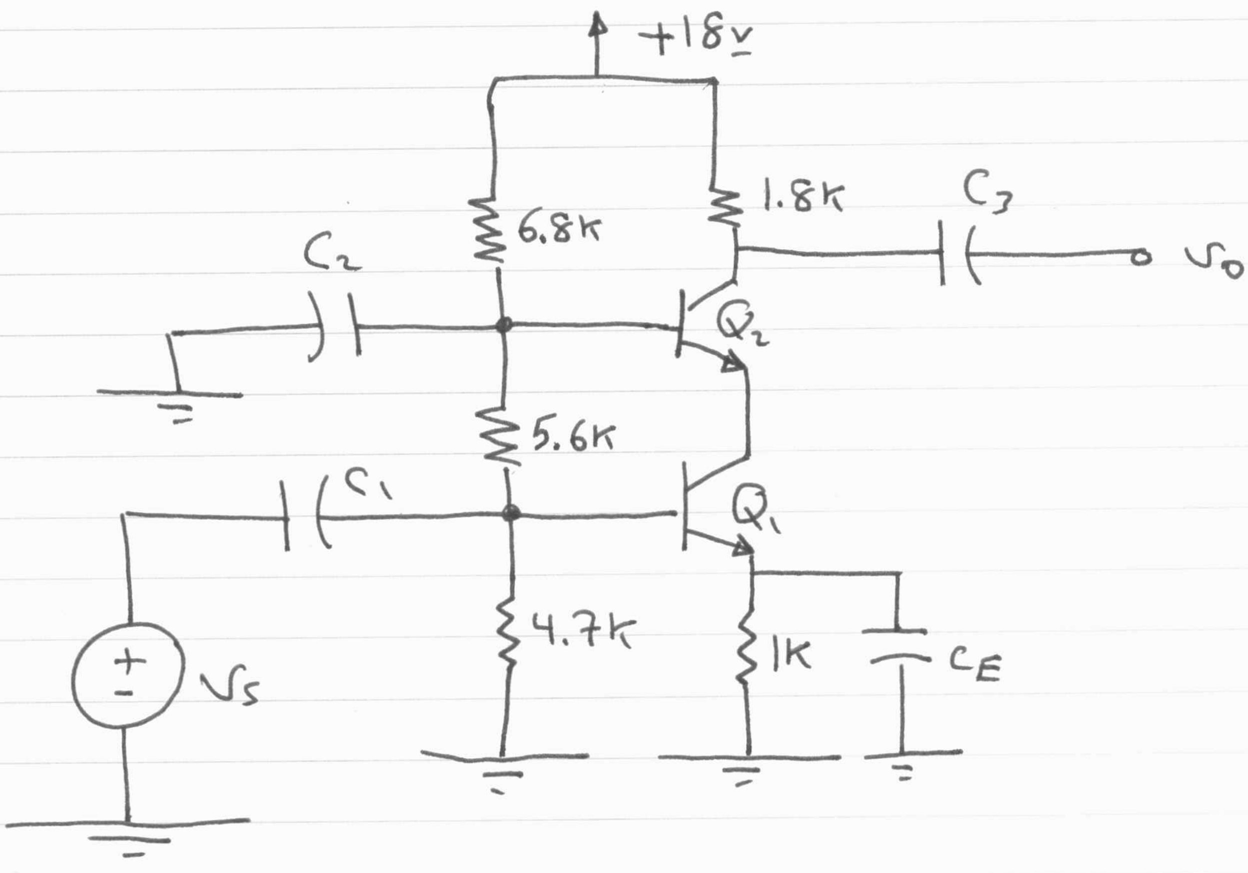
$$\therefore \; h_{ieD} = h_{ie1} + \frac{(1 + h_{fe1}) V_T}{I_{E1}}$$

$$h_{ieD} = h_{ie1} + h_{ie1}$$

$$h_{ieD} = 2 h_{ie1}$$

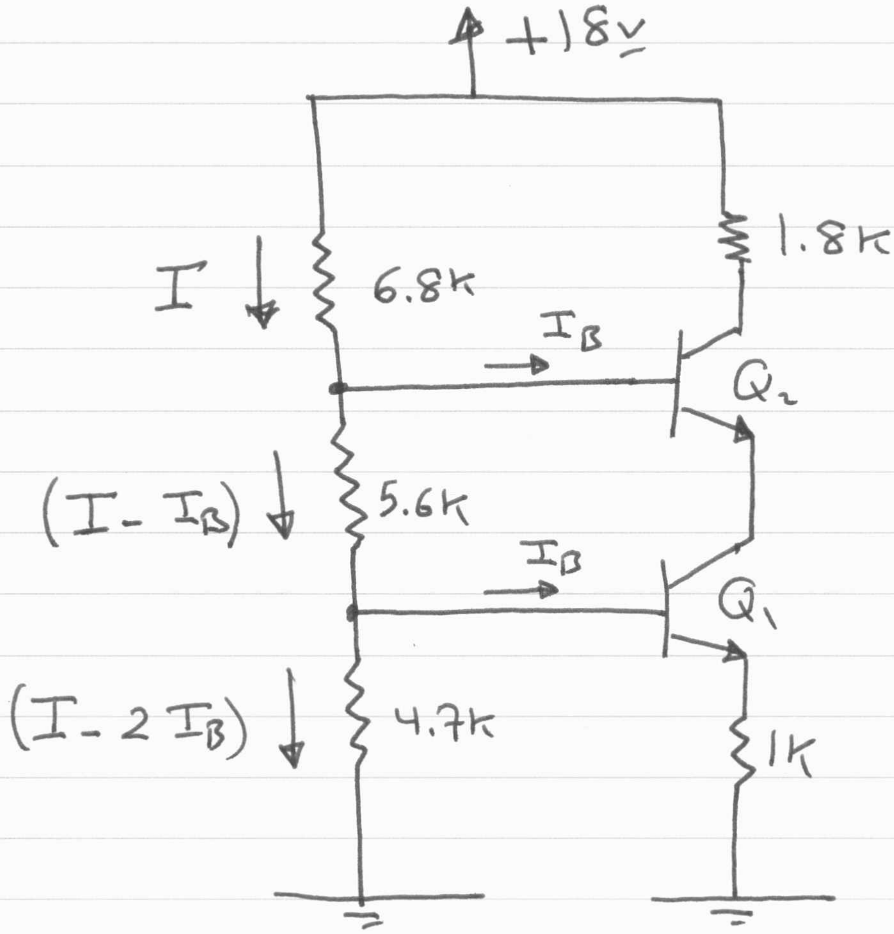
Cascode Amplifier

- Used to amplify video signal
- It has a wide Bandwidth
- It Consists of a CE and CB stages
  or CS and CG stages



$$\beta_1 = \beta_2 = 100$$

Dc Analysis



$$I_{C_1} = I_{E_2} \approx I_{C_2}$$

and since $\beta_1 = \beta_2$

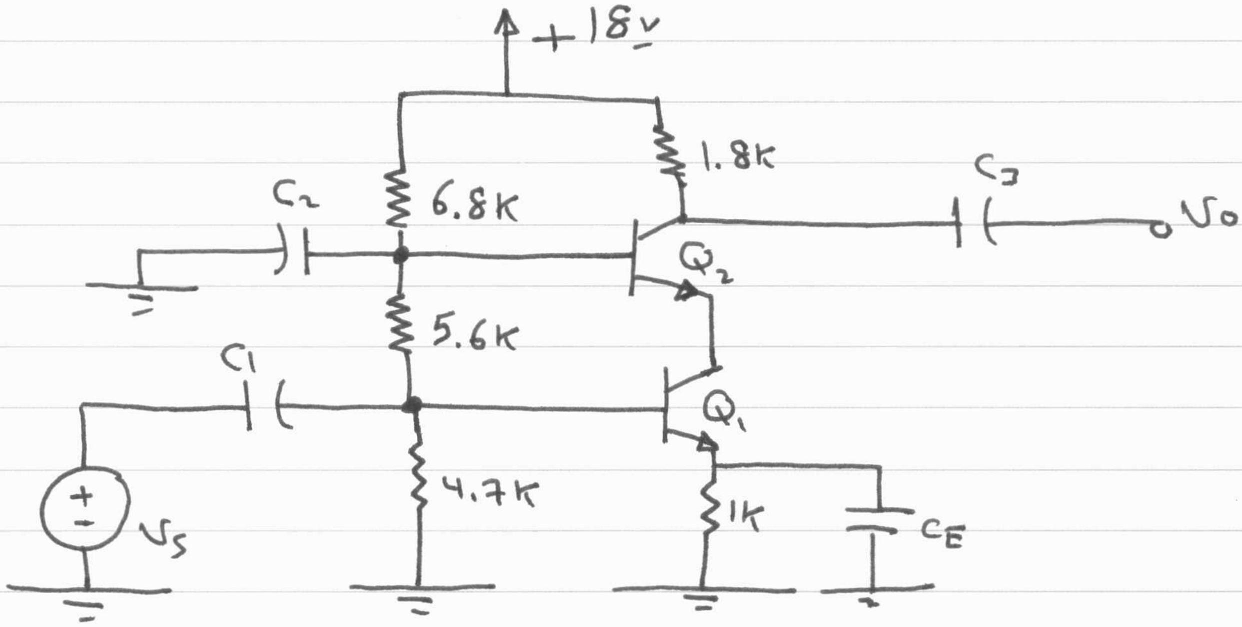
$$I_{B_1} = I_{B2} = I_B$$

$$18 = 6.8k\, I + 5.6k\,(I - I_B) + 4.7k\,(I - 2I_{B_2})$$

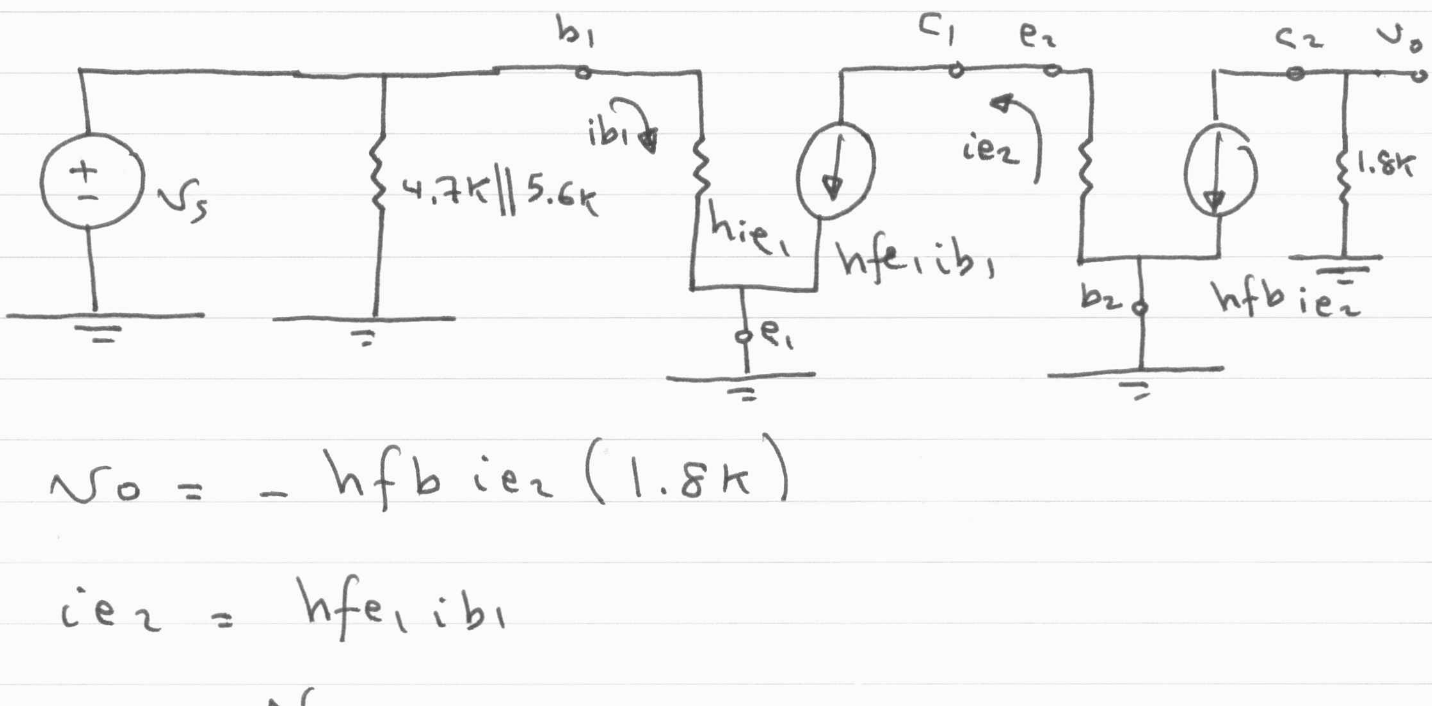
$$18 = 6.8k\, I + 5.6k\,(I - I_B) + V_{BE_1} + 1k\, I_{E_1}$$

Solving for $I_E = 4\,mA$

Ac Small Signal Analysis



Ac small signal equivalent circuit



$$v_o = -h_{fb}\, i_{e2}\,(1.8k)$$

$$i_{e2} = h_{fe1}\, i_{b1}$$

$$i_{b1} = \frac{v_s}{h_{ie1}}$$

$$\therefore A_v = -294$$