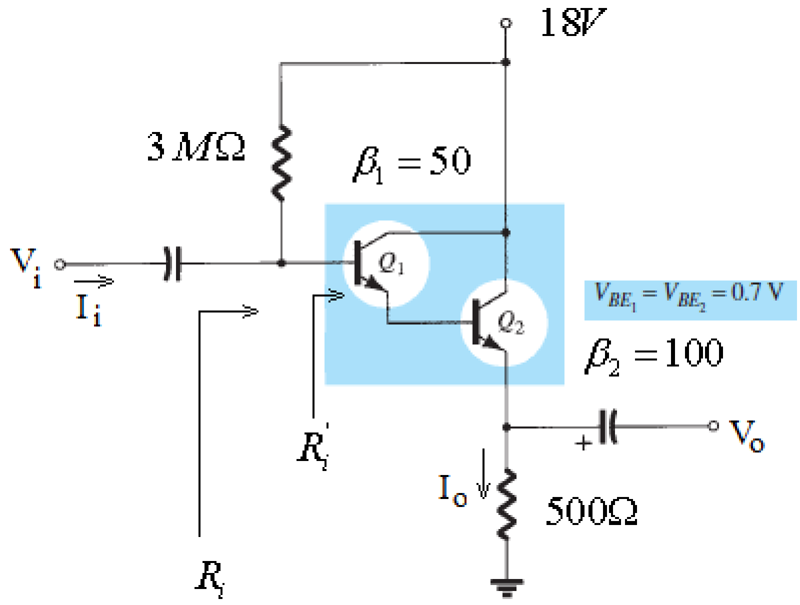
EE101 Tutorial Sheet -7

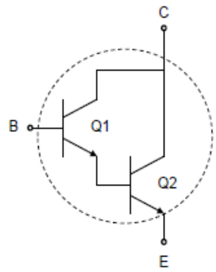
Solutions

1. For the circuit shown, find input resistance R_i and the voltage gain $A_v = \frac{v_o}{v_i}$. Assume V_T = 26 mV and neglect the effect of r_o.



Solution

For the Darlington pair



$$I_C = I_{c1} + I_{c2} = \beta_1 I_B + \beta_2(\beta_1 + 1) I_B$$

$$\beta_D = \frac{I_C}{I_B} = \beta_1\beta_2 + \beta_1 + \beta_2$$

For the given transistor configuration

$$\beta_D = 5150$$

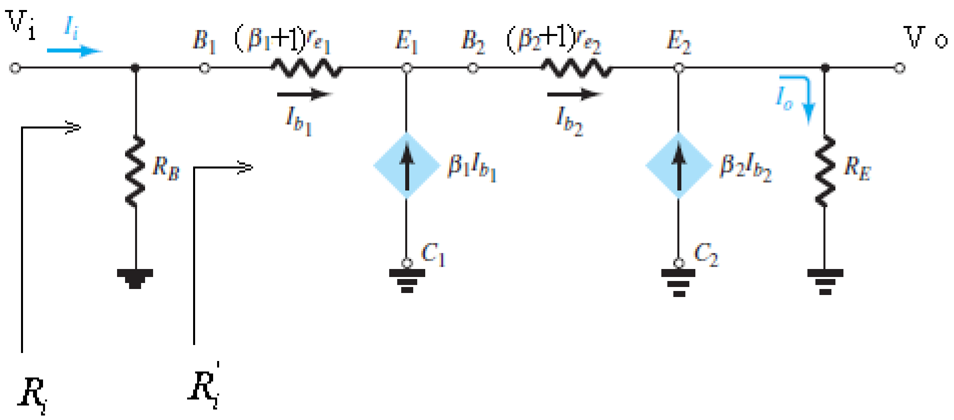
$$I_C \approx I_E$$

$$V_{CC} = I_B R_B + V_{BE1} + V_{BE2} + I_E R_E$$

$$I_B \cong \frac{V_{CC} - (V_{BE1} + V_{BE2})}{R_B + \beta_D R_E} = \frac{18 - 1.4}{3 + 2.575} \cong 3\,\mu A$$

$$I_{E1} = 51 \times 3 = 153\ \mu A \quad r_{e1} = \frac{26 \times 10^{-3}}{153 \times 10^{-6}} \cong 164\Omega$$

$$I_{E2} = 5150 \times 3 = \mu A \quad r_{e2} = \frac{26 \times 10^{-3}}{15450 \times 10^{-6}} \cong 1.7\Omega$$



For transistor Q_2, the current flowing through the emitter resistance R_E is $(\beta_2 + 1)i_{b_2}$. Therefore the input resistance for transistor Q_2 can be deduced as $R_{i_{Q2}} = (\beta_2 + 1)(r_{e_2} + R_E)$.

Note that transistor Q_1 sees $R_{i_{Q2}}$ as an external resistance connected at its emitter terminal. So the input resistance for transistor Q_1 can be given as

$$R_i^{'} = \left[r_{e1} + (\beta_2 + 1)(r_{e2} + R_E)\right](\beta_1 + 1) \cong 2.6\ M\Omega$$

$$R_i = R_B \parallel R_i^{'} = 1.4 M\Omega$$

Current gain and voltage gain

$$I_0 = (\beta_1 + 1)(\beta_2 + 1)i_{b1} \qquad i_{b1} = \frac{R_B}{R_B + R_i^{'}} I_i \qquad A_I = \frac{I_0}{I_i} = (\beta_1 + 1)(\beta_2 + 1)\frac{R_B}{R_B + R_i^{'}} \cong 2760$$

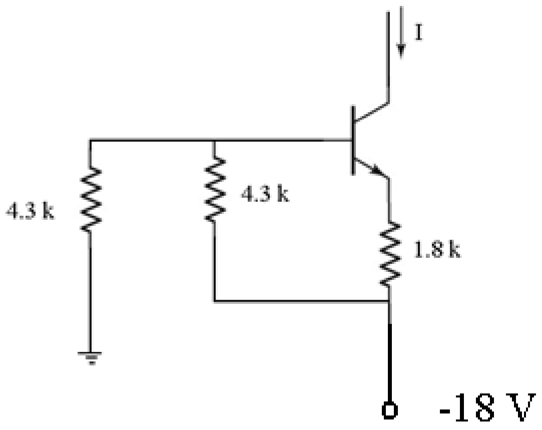
$$V_o = I_0 R_E$$

$$V_i = R_i I_i$$

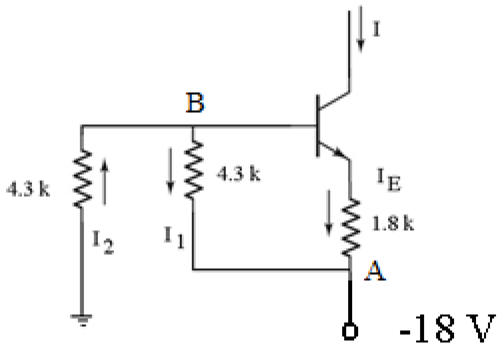
$$A_v = \frac{V_o}{V_i} = A_I \frac{R_E}{R_i} = 0.986$$

Note: Despite large current gain achieved due to Darlington configuration, the voltage gain turns out to be ***unity*** as the given circuit is an emitter follower.

2. Find the current I for the circuit shown below. The transistor has $\beta = 100$. Assume that the transistor is in active region and $V_{BE} = 0.7\ V$.



Solution



Consider that the currents I_1 I_2 I_E marked in the circuit are in mA.

Applying KVL in outer loop we have

$$4.3(I_1 + I_2) = 18 \qquad (1)$$

On applying KCL at node B, we have

$$I_2 = I_1 + \frac{I_E}{101} \qquad (2)$$

From (1) and (2) we have

$$2I_1 + \frac{I_E}{101} = \frac{18}{4.3} \qquad (3)$$

On equating the voltage drop across terminals A-B, we have

$$4.3I_1 = V_{BE} + 1.8I_E = 0.7 + 1.8I_E \qquad (4)$$

From (3) and (4) on solving for I_E, we get

$$I \simeq I_E = 4.56 \text{ mA}$$