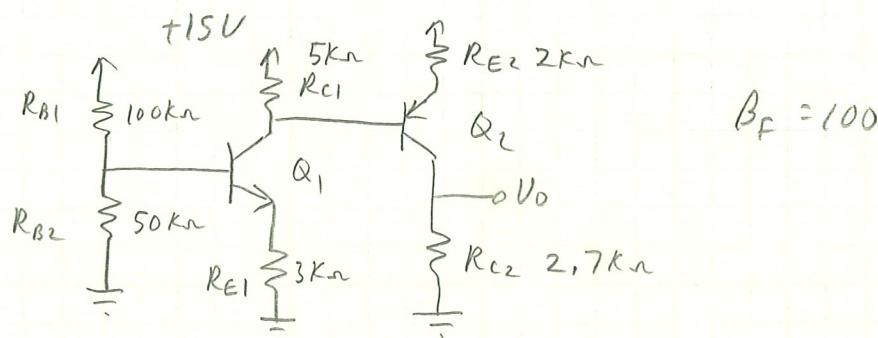


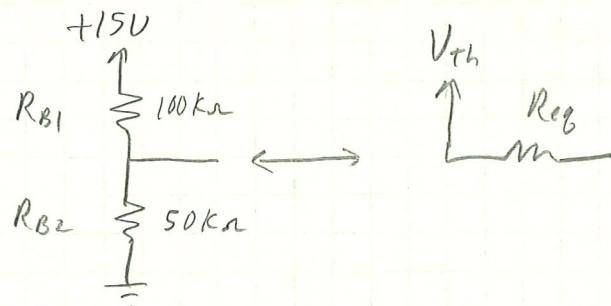
## 1) another FAR BJT example



Find Q-points for  $Q_1$ ,  $Q_2$  and  $V_o$

Solution

① Thevenin equivalent  $Q_1$  base circuit

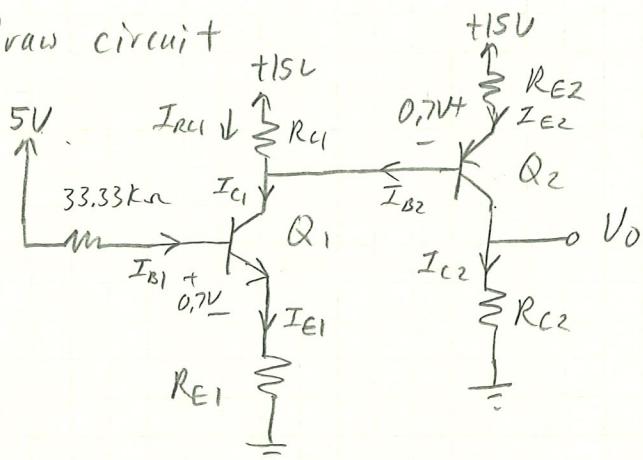


$$V_{th} = 15 \frac{R_{B2}}{R_{B1} + R_{B2}} = \frac{15(50k)}{150k} = 5V$$

$$R_{th} = R_{B1} // R_{B2} = \frac{(50k)(100k)}{150k} = 33.33k\Omega$$

; redraw circuit

assume FAR



$$KVL: 5 - I_{B1} 33.33K - 0.7 - I_{E1} R_{E1} = 0$$

$$I_C = \beta_F I_B = \alpha_F I_E$$

$$\therefore I_E = \frac{\beta_F}{\alpha_F} I_B = (\beta_F + 1) I_B = 101 I_B$$

$$\therefore 5 - I_{B1} 33.33K - 0.7 - 101 I_B (3K) = 0$$

$$4.3 = I_B (33.33K + 303K) = 0$$

$$I_{B1} = \frac{4.3}{336.33K} = 12.8 \mu A$$

$$\therefore I_{E1} = (\beta_F + 1) I_{B1} = 101 (I_{B1}) = 1.29 mA$$

$$\therefore I_{C1} = \beta_F I_{B1} = 100 (I_{B1}) = 1.28 mA$$

$$\therefore V_{E1} = I_{E1} R_{E1} = (1.29mA)(3K) = 3.87V$$

$$V_{B1} = 0.7 + V_{E1} = 4.57V$$

$$V_{C1} = ??$$

examine  $V_{B2}$

$$V_{B2} = 15 - I_{Rc1} R_{c1} = 15 - I_{E2} R_{E2} - 0.7$$

$$\therefore I_{Rc1} R_{c1} = I_{E2} R_{E2} + 0.7$$

$$(I_{C1} - I_{B2}) R_{c1} = (\beta + 1) I_{B2} R_{E2} + 0.7$$

$$R_{c1} I_{C1} - 0.7 = I_{B2} (R_{c1} + (\beta + 1) R_{E2})$$

$$I_{B2} = \frac{R_{c1} I_{C1} - 0.7}{R_{c1} + (\beta + 1) R_{E2}}$$

$$= \frac{5K(1.28mA) - 0.7}{5K + 101(2K)}$$

$$= 28 \mu A$$

$$\therefore V_{C1} = 15 - (I_{C1} - I_{B2}) R_{c1}$$

$$= 15 - (1.28mA - 28 \mu A) 5K$$

$$= 8.74V = V_{B2}$$

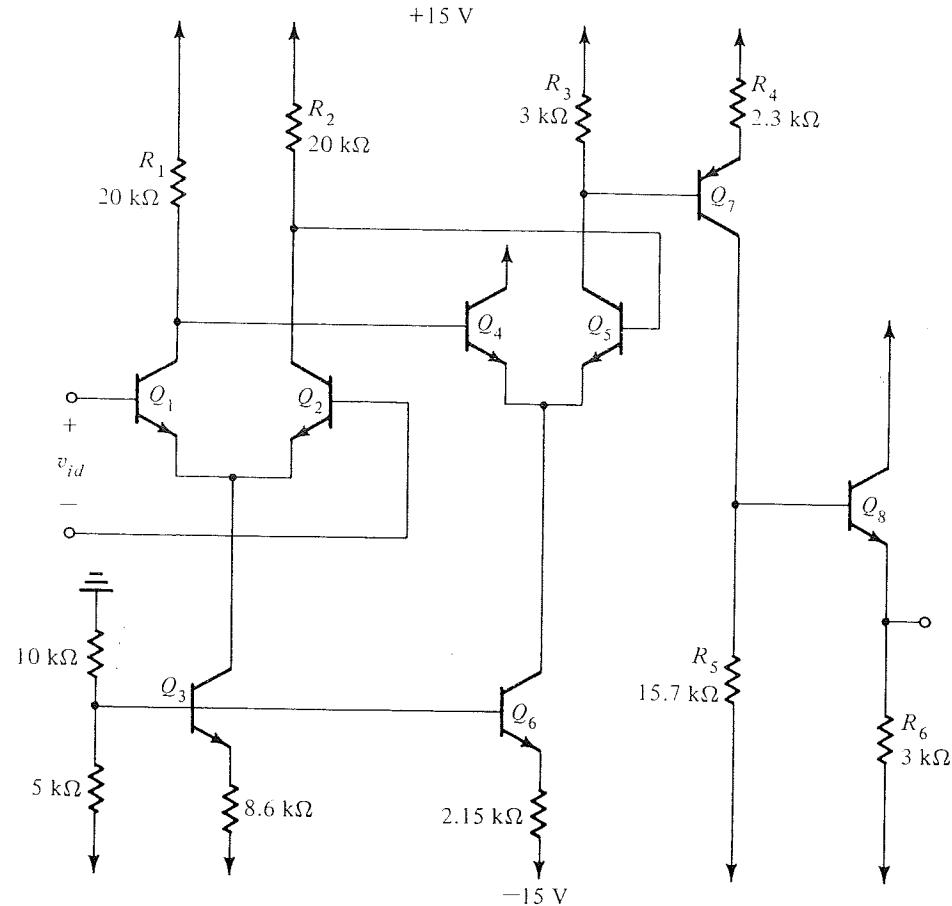


Fig. 10.28 A multistage amplifier circuit (Example 10.4).

transistor  $Q_7$ , provides the essential function of *shifting the dc level* of the signal. Thus while the signal at the collector of  $Q_5$  is not allowed to swing below the voltage at the base of  $Q_5$  (+10 V), the signal at the collector of  $Q_7$  can swing negative (and positive, of course). From our study of op amps in Chapter 3 we know that the output terminal of the op amp should be capable of positive and negative voltage swings. Therefore every op-amp circuit includes a *level-shifting* stage. Although the use of the complementary *pnp* transistor provides a simple solution to the level-shifting problem, other forms of level shifters exist, one of which will be discussed in Chapter 13.

Finally, we note that the output stage consists of emitter follower  $Q_8$  and that ideally the dc level at the output is zero volts (as was calculated in Example 10.3).

#### Example 10.4

Use the dc bias quantities evaluated in Example 10.3 and analyze the circuit in Fig. 10.28 to determine the input resistance, the voltage gain, and the output resistance.

$$\therefore I_{E2} = (\beta + 1) I_{B2} = 101(28\mu A) = 2.78 mA$$

$$V_{E2} = 15 - R_{E2} I_{E2} = 15 - 2k(2.78mA) = 9.44V$$

$$\therefore I_{C2} = \beta I_B = 100(28\mu A) = 2.75mA$$

$$V_o = V_{C2} = I_{C2} R_{C2} = 2.75mA(2.7k) = 7.43V$$

$$\therefore V_{CE1} = V_C - V_E = 8.74 - 3.87 = 4.87V$$

$$V_{CE2} = V_C - V_E = 7.43 - 9.44 = -2.01V$$

FAR: NPN:  $V_C \geq V_B \geq V_E$

$$8.74V > 4.57V > 3.87V \quad \checkmark$$

FAR: PNP:  $V_E \geq V_B \geq V_C$

$$9.44V > 8.74V > 7.43V \quad \checkmark$$

Q-points:  $Q_1 (I_C = 1.28mA, V_{CE} = 4.87V)$

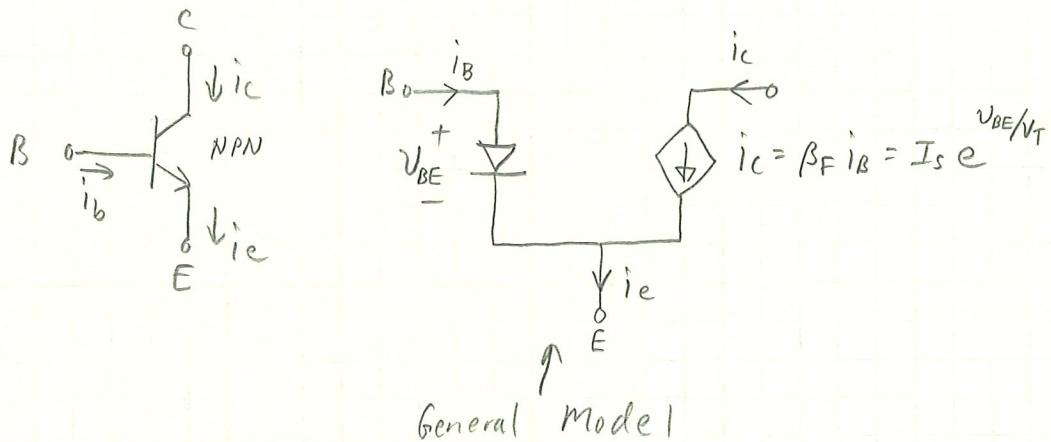
$Q_2 (I_C = 2.75mA, V_{CE} = -2.01V)$

$$V_o = 7.43V$$

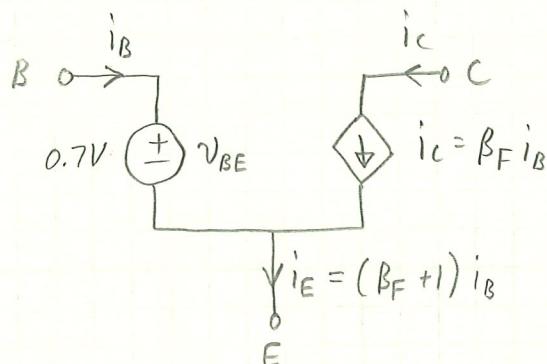
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2. Another FAR. model for the BJT

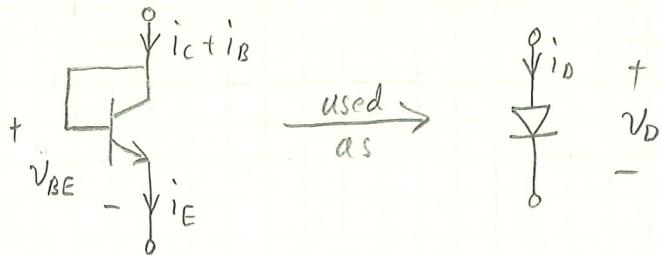


simplified BJT model with  $V_{BE} = 0.7V$ :



### 3. Diodes in BJT IC's

Consider this:



From BJT transport model:

$$\begin{aligned} i_b &= i_c + i_b = \left( I_s + \frac{I_s}{\alpha_F} \right) \left( e^{\frac{V_{BE}}{V_T}} - 1 \right) \\ &= \frac{I_s}{\alpha_F} \left( e^{\frac{V_b}{V_T}} - 1 \right) \end{aligned}$$

From Ch 3: pn junction diode equation:

$$i_d = I_s \left( e^{\frac{V_o}{V_T}} - 1 \right)$$

Notice: the BJT diode reverse saturation current:  $\frac{I_s}{\alpha_F}$   
is determined by the BJT parameters:  $I_s$  &  $\alpha_F$