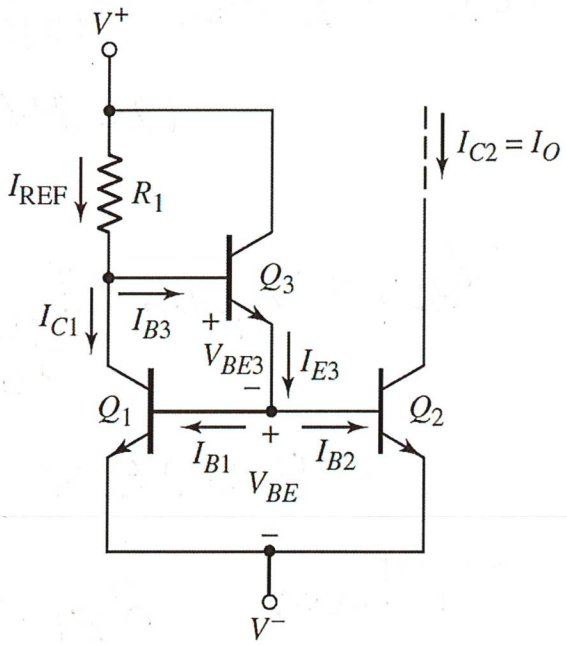
ENEL 469: Analog Electronic Circuits

Quiz-3, Fall 2023

Total marks: 24; Time: 11:00 am – 12:10 pm

ID (Optional)	First Name (PRINT)	Last Name (PRINT)

1. [**Total 3**] Consider the following current compensation current mirror. All the transistors are identical and operate in the active region. The transistors have large β, i.e., β = ∞, but have very low V_A value.

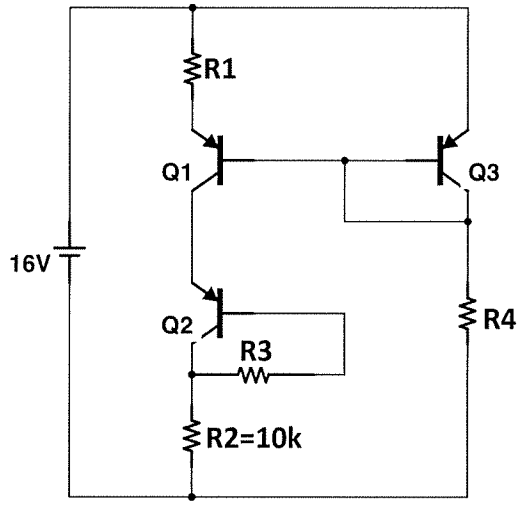


Would the following equation be applicable to address the effect of V_A in the output current?

$$\frac{I_{C2}}{I_{C1}} = \frac{I_o}{I_{Ref}} = \frac{1 + \frac{V_{CE2}}{V_A}}{1 + \frac{V_{CE1}}{V_A}}$$

Yes

2. [**Total 6**] In the following current source, all transistors are identical and $\beta = \infty$ (i.e., ignore all base currents). The base-emitter voltage of Q3 is $|V_{BE,Q3}| = 0.65V$, the scale current of Q2 is 7.77×10^{-14} A, and the voltage across resistor R2 (10k) is 1.2 V.
   Determine:
   a) [**3**] The resistor R1 and
   b) [**3**] The resistor R4



$$I_{C2} = I_{E2} = I_{E1} = \frac{1.2}{10K}$$

$$= 120\,\mu A$$

$$V_{BE1} = V_T \ln\left(\frac{I_{C1}}{I_S}\right)$$

$$= 0.529\ V$$

Ans: R1 = 1008 Ω

Ans: R4 = 26.42 K

Thus, $R_{E1} = \frac{0.65 - 0.529}{120 \times 10^{-6}} = 1008\ \Omega$

We know,

$$I_o R_E = V_T \ln\left(\frac{I_{Ref}}{I_o}\right)$$

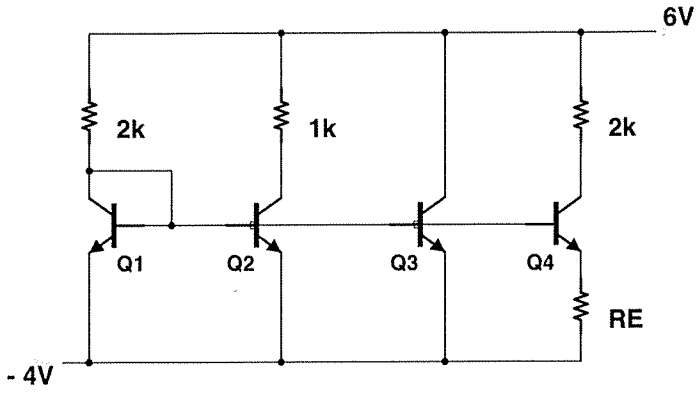
Here, $R_E = 1008$, $I_o = 120\,\mu A$.

Thus, $I_{Ref} = 0.581\ mA$

$$R_4 = \frac{16 - 0.65}{0.581 \times 10^{-3}}$$

$$= 26.42\ K$$

3. [**Total 4=1+1+2**] Assume all transistors are identical in the following circuit. For simplicity, consider $|V_{BE,ON}| = 0.7V$ and $\beta = V_A = \infty$. Determine the values of IC2, IC3, and RE. Given that IC4 = 1 mA.



$$I_{C1} = \frac{10 - 0.7}{2K}$$

$$= 4.65\ mA$$

Ans: IC2 = 4.65 mA

Ans: IC3 = 4.65 mA

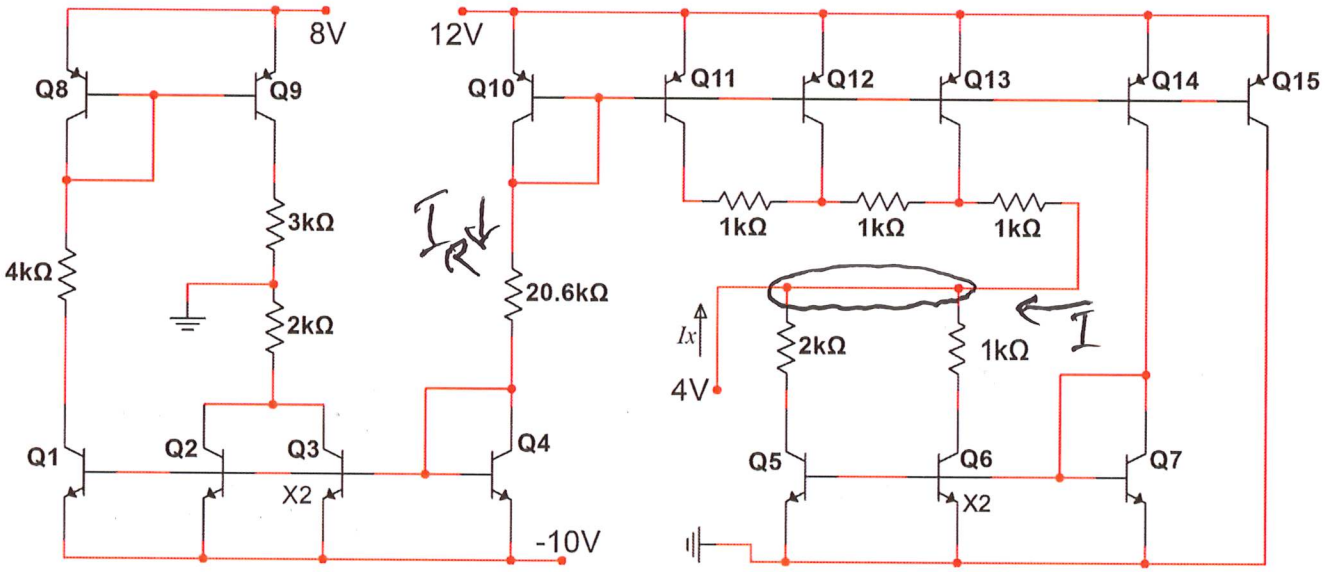
Ans: RE = 38.42 Ω

$$I_{C4} R_E = V_T \ln\left(\frac{I_{C1}}{I_{C4}}\right)$$

$$= 0.0384\ V$$

$$\therefore R_E = 38.42\ \Omega$$

4. [**Total 4**] Consider the following circuit where all transistors are identical. Given that $|V_{BE,ON}| = 0.7V$, and $\beta = V_A = \infty$. Determine the current I_X as indicated in the circuit.



Ans: I_X = 0

$$I_R = \frac{22 - 0.7 - 0.7}{20.6 \times 10^3} = 1\,mA$$

$$I = I_{C11} + I_{C12} + I_{C13} = 3\,mA$$

Also, $I_{C5} = 1\,mA$ and $I_{C6} = 2\,mA$

By KCL, $I_x = I_{C5} + I_{C6} - I$

$= 0$

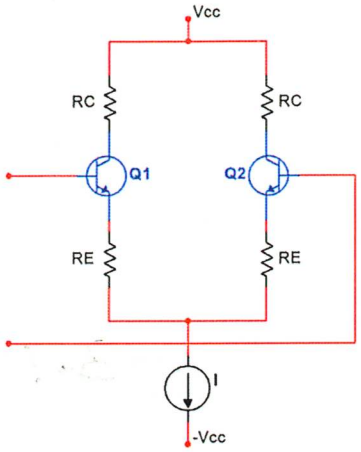
5. [**Total 3**] Consider the following circuit where the transistors are identical. The transfer characteristics of the circuit are shown to the right of the circuit. Considering the given information in the circuit and the characteristic curves, which of the following arguments is correct?

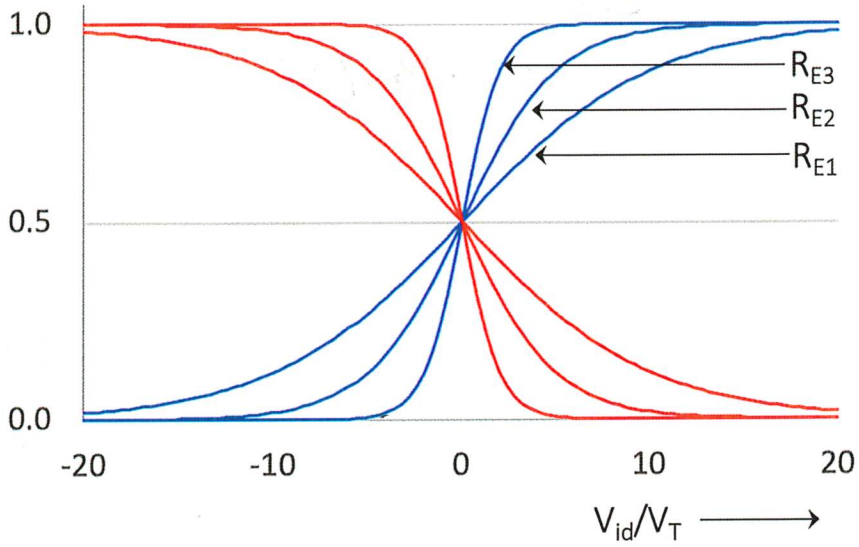
a) $R_{E1} > R_{E2} > R_{E3}$

b) $R_{E1} < R_{E2} < R_{E3}$

c) $R_{E1} = R_{E2} = R_{E3}$

d) None of the above



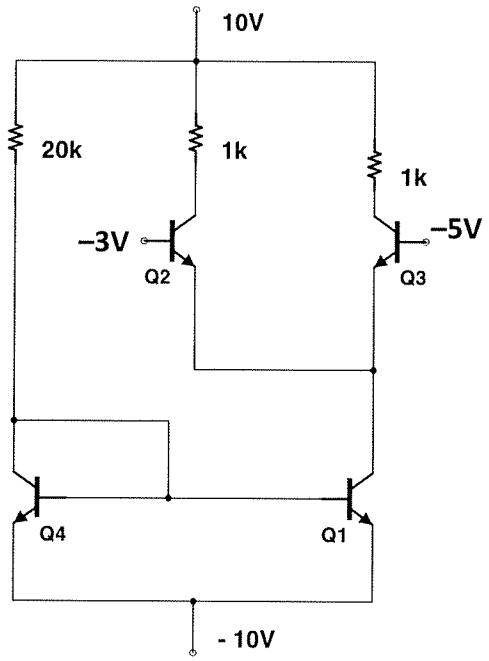


6. [4] In the following circuit, $|V_{BE,ON}| = 0.7V$, and $\beta = V_A = \infty$. Determine the emitter voltage V_{E3} or V_{E2}.

Q_2 is ON
Q_3 is OFF

Thus,

$V_{E2} = -3 - 0.7$
$= -3.7V$



Ans: $V_{E2} = V_{E3} = -3.7V$

$g_m = \frac{I_C}{V_T}$ $r_e = \frac{V_T}{I_E}$ $r_\pi = \frac{V_T}{I_B}$ $r_\pi = \frac{\beta}{g_m}$ $r_e = \frac{\alpha}{g_m}$

$A_{vo} = -g_m \times (R_C || r_o)$ $Voltage\ gain = \frac{Total\ resistance\ in\ the\ collector}{Total\ resistance\ in\ the\ emitter}$

$A_{vo} = \frac{g_m R_C}{1+g_m R_E}$ $I_C = I_S e^{V_{BE}/V_T}$ $f_C = \frac{1}{2\pi RC}$ $f_C = \frac{1}{2\pi\sqrt{LC}}$ $|Z_C| = \frac{1}{2\pi fC}$

$\frac{I_o}{I_{REF}} = \frac{1}{1+\frac{2}{\beta}}$ $\frac{I_o}{I_{REF}} = \frac{1}{1+\frac{2}{\beta^2}}$ $R_{in} \approx \frac{1}{g_m}$ $\frac{I_o}{I_{REF}} = \left[\frac{1}{1+\frac{2}{\beta}}\right]\left[\frac{1+\frac{V_{CE2}}{V_A}}{1+\frac{V_{CE1}}{V_A}}\right]$

$R_0 = [1 + g_m(R_E \parallel r_\pi)]r_0$ $I_0 R_E = V_T ln\left(I_{REF}/I_0\right)$ $R_o = \frac{\beta r_o}{2}$