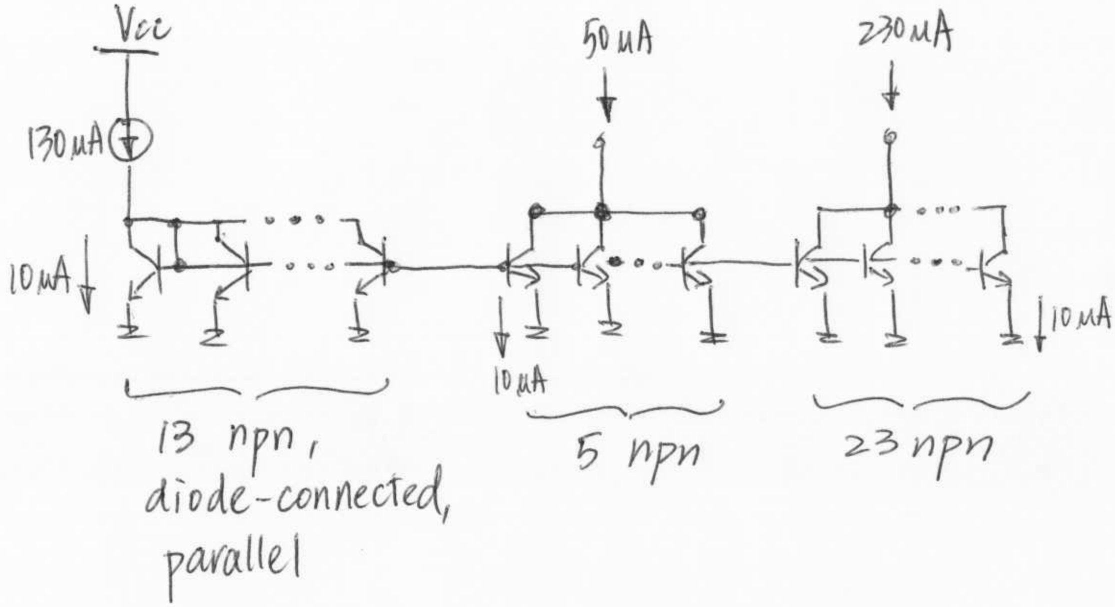
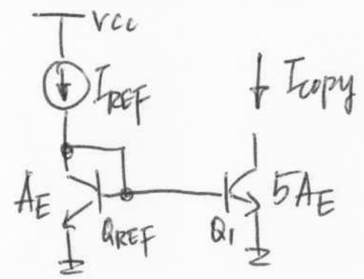
43.



All the bases are the same node.

If the area of BJT is flexible, the 5-npn group can be replaced by one BJT that is 5 times as big in area. Similar concept applies to 23-npn grouping.

4b (a)



Q_1 has I_s 5 times as that of Q_{REF}

$\Rightarrow I_{C_{REF}} = I_{copy}/5$

By KCL,

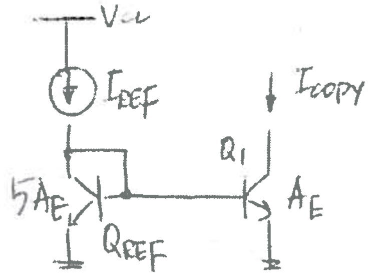
$$I_{REF} = I_{C,REF} + \frac{I_{C_{REF}}}{\beta} + \frac{I_{copy}}{\beta}$$

$$= \frac{I_{copy}}{5}\left(1+\frac{1}{\beta}\right) + \frac{I_{copy}}{\beta}$$

$$\therefore I_{copy} = I_{REF}\left(\frac{5\beta}{\beta+6}\right)$$

$$\therefore \text{error} = \frac{I_{copy}}{I_{REF}} = \frac{5\beta}{\beta+6}$$

(b)



Q_1 & Q_{REF} have the same V_{BE}, but area of Q_{REF} is 5 times larger

$\Rightarrow I_{C,REF} = 5 \cdot I_{copy}$

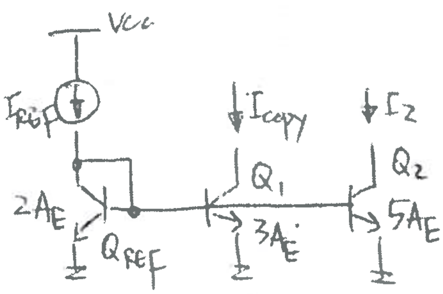
By KCL,

$$I_{REF} = I_{C,REF} + \frac{I_{C,REF}}{\beta} + \frac{I_{copy}}{\beta}$$

$$= I_{copy} \cdot 5 \left(1 + \frac{1}{\beta}\right) + I_{copy}\left(\frac{1}{\beta}\right)$$

$$\therefore I_{copy} = I_{REF}\left(\frac{\beta}{5\beta + 6}\right)$$

(c)



Q_1 & Q_{REF} have identical V_{BE}, but area of Q_1 is 1.5 times larger.

$\Rightarrow 3 I_{C,REF} = 2 I_{copy}$

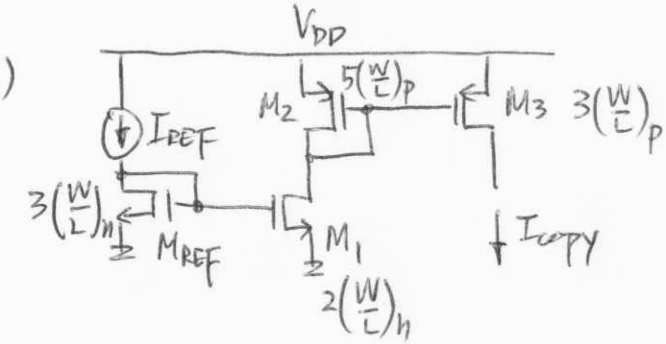
By KCL,

$$I_{REF} = I_{C,REF} + I_{C,REF}/\beta + I_{copy}/\beta + I_2/\beta$$

$$= I_{copy}\left(\frac{2}{3}\right)\left[\left(1 + 1/\beta\right)\right] + \left[1/\beta + 5/3\left(\frac{1}{\beta}\right)\right] I_{copy}$$

$$\rightarrow I_{copy} = \cancel{\frac{9\beta}{6\beta + 22} I_{REF}} \quad \frac{3\beta}{2\beta + 10} I_{REF}$$

52. (a)

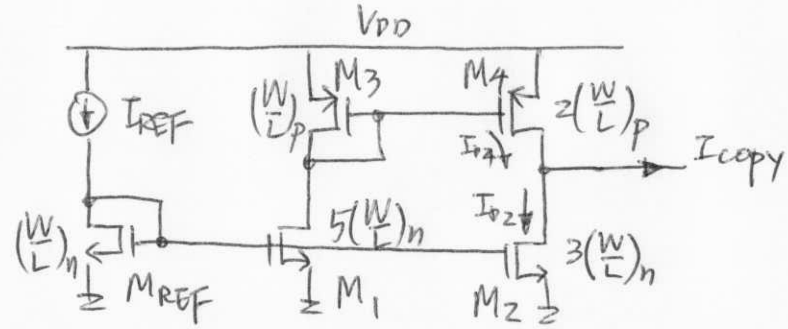


$V_{GS,REF} = V_{GS,1}$: $\Rightarrow I_{D,1} = \frac{2}{3} I_{REF}$

$V_{GS,2} = V_{GS,3}$: $\Rightarrow I_{copy} = \frac{3}{5} I_{D,2} = \frac{3}{5} I_{D,1}$

$= \frac{3}{5} \cdot \left(\frac{2}{3} I_{REF}\right) = \frac{2}{5} I_{REF}$

(b)



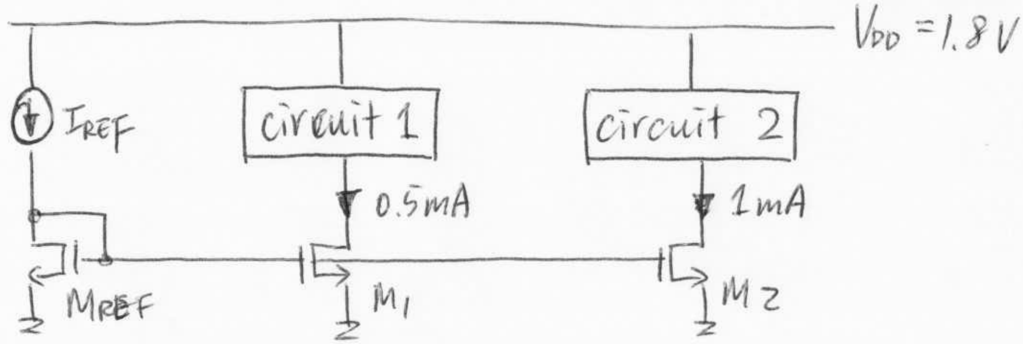
$V_{GS,REF} = V_{GS,1}$: $I_{D,1} = 5 I_{REF}$

$V_{GS,3} = V_{GS,4}$: $I_{D4} = 2 I_{D3} = 2 I_{D,1} = 10 I_{REF}$

$V_{GS,REF} = V_{GS,2}$: $I_{D2} = 3 I_{REF}$

$\therefore I_{copy} = I_{D4} - I_{D2} = 7 I_{REF}$.

65.



power budget = 3 mW.

$$\text{power} = V_{DD}(I_{REF} + 0.5mA + 1mA)$$

$$\Rightarrow I_{REF} = \frac{\text{power}}{V_{DD}} - 0.5mA - 1mA \approx 0.17mA$$

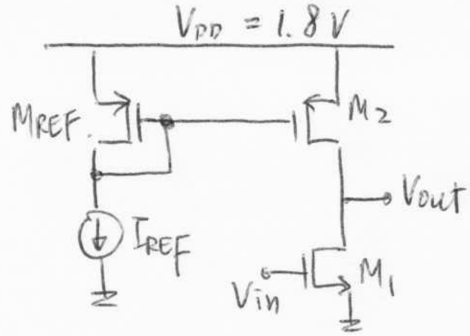
Assuming M_1 & M_2 operate in saturation,

If M_{REF} has $\left(\frac{W}{L}\right)_{REF}$, then

$$\frac{(W/L)_1}{(W/L)_{REF}} = \frac{I_1}{I_{REF}} = \frac{50}{17}$$

$$\frac{(W/L)_2}{(W/L)_{REF}} = \frac{I_2}{I_{REF}} = \frac{100}{17}$$

66.



$A_v = -20$

power = 2mW

$\left(\frac{W}{L}\right)_1 = \frac{20}{0.18}$ $\quad \lambda_n = 0.1V^{-1}$

$\lambda_p = 0.2V^{-1}$

$$R_{out} = r_{o2} \parallel r_{o1} = \frac{1}{\lambda_n I_{D_1} + \lambda_p I_{D_1}}$$

$$\Rightarrow A_v = -G_m R_{out} = \frac{-g_{m_1}}{\lambda_n I_{D_1} + \lambda_p I_{D_1}} = -\frac{2I_{D_1}/(V_{GS_1}-V_{TH})}{I_{D_1}(\lambda_n+\lambda_p)}$$

$$\Rightarrow -20 = -\frac{2}{(V_{GS_1}-V_{TH})(\lambda_n+\lambda_p)}$$

$$\Rightarrow V_{GS_1} = \frac{1}{10(\lambda_n+\lambda_p)} + V_{TH_n}$$

$$= \frac{1}{10(0.1+0.2)V^{-1}} + 0.4V \approx 0.73\ V$$

$$\Rightarrow I_{D_1} = \frac{1}{2}\mu_n C_{ox}\left(\frac{W}{L}\right)_1 (V_{GS_1} - V_{TH_n})^2.$$

$$= \frac{1}{2}\left(100\ \frac{\mu A}{V^2}\right)\left(\frac{20}{0.18}\right)(0.33V)^2 \approx 0.61\ mA$$

$\because$ power $= V_{DD}(I_{REF} + I_{D_1})$

$$\Rightarrow I_{REF} = \frac{\text{power}}{V_{DD}} - I_{D_1} = \frac{2mW}{1.8V} - 0.61mA$$

$$\approx 0.5\ mA$$

$\therefore$ if M_{REF} has $\left(\frac{W}{L}\right)_{REF}$, then

$$\frac{(W/L)_2}{(W/L)_{REF}} = \frac{I_{D2}}{I_{REF}} = \frac{61}{50} \approx 1.2$$