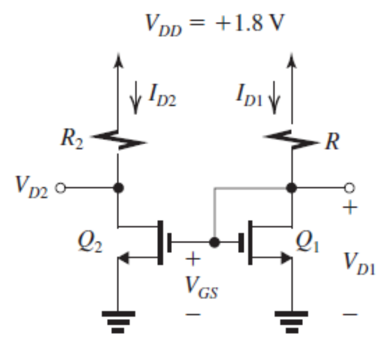
Homework 4 – Solutions
Problems (not review questions): 5.46, 5.50, 5.61

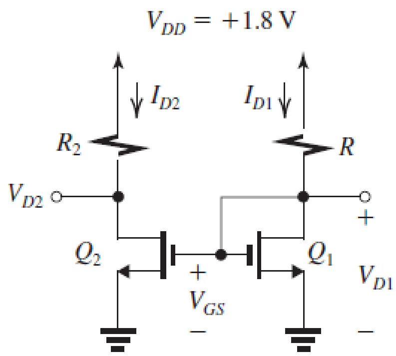
Solutions for some of the problems are on mycourses:
Book_solutions.pdf ;
Solution for 5.46: a) R=21 KOhm, (b) W2=14.4 µm,
R2=3.1 KOhm

Circuit for 5.46→

5.46



5.46



(a) $I_{D1} = 50\ \mu$A

$$0.05 = \frac{1}{2} \times 0.4 \times \frac{1.44}{0.36} V_{OV}^2$$

$\Rightarrow V_{OV} = 0.25$ V

$V_{GS1} = V_t + V_{OV}$

$= 0.5 + 0.25 = 0.75$ V

$V_{D1} = V_{GS1} = 0.75$ V

$$R = \frac{V_{DD} - V_{D1}}{I_{D1}} = \frac{1.8 - 0.75}{0.05} = 21\ \text{k}\Omega$$

(b) Note that both transistors operate at the same V_{GS} and V_{OV}, and

$I_{D2} = 0.5$ mA

But

$$I_{D2} = \frac{1}{2} k_n \left(\frac{W_2}{L_2}\right) V_{OV}^2$$

$$0.5 = \frac{1}{2} \times 0.4 \times \frac{W_2}{0.36} \times 0.25^2$$

$\Rightarrow W_2 = 14.4\ \mu$m

which is 10 times W_1, as needed to provide $I_{D2} = 10 I_{D1}$. Since Q_2 is to operate at the edge of saturation,

$V_{DS2} = V_{OV}$

Thus,

$V_{D2} = 0.25$ V

and

$$R_2 = \frac{V_{DD} - V_{D2}}{I_{D2}}$$

$$= \frac{1.8 - 0.25}{0.5} = 3.1\ \text{k}\Omega$$

5.50 Refer to Fig. P5.50. Both Q_1 and Q_2 are operating in saturation at $I_D = 0.5$ mA. For Q_1,

$$I_D = \frac{1}{2}\mu_n C_{ox}\frac{W_1}{L_1}\, V_{OV1}^2$$

$$0.5 = \frac{1}{2} \times 0.25 \times \frac{W_1}{L_1}(1 - 0.5)^2$$

$$\Rightarrow \frac{W_1}{L_1} = 16$$

$W_1 = 16 \times 0.25 = 4\ \mu\text{m}$

For Q_2, we have

$$I_D = \frac{1}{2}\mu_n C_{ox}\left(\frac{W_2}{L_2}\right)V_{OV2}^2$$

$$0.5 = \frac{1}{2} \times 0.25 \times \frac{W_2}{L_2}(1.8 - 1 - 0.5)^2$$

$$\Rightarrow \frac{W_2}{L_2} = 44.4$$

$W_2 = 44.4 \times 0.25 = 11.1$

$$R = \frac{2.5 - 1.8}{0.5} = 1.4\ \text{k}\Omega$$

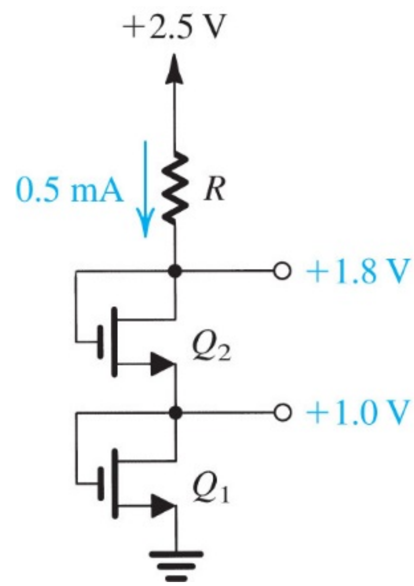


Figure P5.50

5.61 Refer to the circuit in Fig. P5.61.

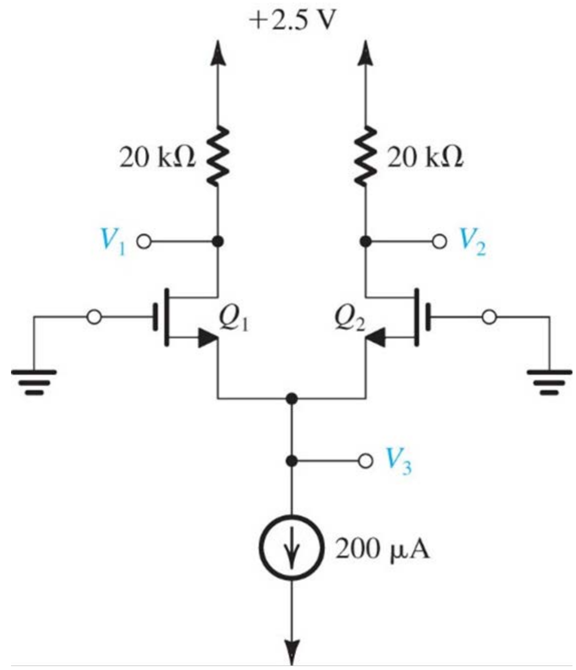


Figure P5.61

(a) Q_1 and Q_2 are matched. Thus, from symmetry, we see that the 200-μA current will split equally between Q_1 and Q_2:

$I_{D1} = I_{D2} = 100\ \mu\text{A}$

$V_1 = V_2 = 2.5 - 0.1 \times 20 = 0.5\ \text{V}$

To find V_3, we determine V_{GS} of either Q_1 and Q_2 (which, of course, are equal),

$$I_{D1} = \frac{1}{2}\,\mu_n C_{ox}\left(\frac{W}{L}\right)_1 (V_{GS} - V_t)^2$$

$$100 = \frac{1}{2} \times 125 \times 20 \times (V_{GS} - 0.7)^2$$

$\Rightarrow V_{GS} = 0.983\ \text{V}$

Thus,

$V_3 = -0.983\ \text{V}$

(b) With $V_{GS1} = V_{GS2}$, but $(W/L)_1 = 1.5(W/L)_2$, transistor Q_1 will carry a current 1.5 times that in Q_2, that is,

$I_{D1} = 1.5 I_{D2}$

But,

$I_{D1} + I_{D2} = 200\ \mu\text{A}$

Thus

$I_{D1} = 120\ \mu\text{A}$

$I_{D2} = 80\ \mu\text{A}$

$V_1 = 2.5 - 0.12 \times 20 = 0.1\ \text{V}$

$V_2 = 2.5 - 0.08 \times 20 = 0.9\ \text{V}$

To find V_3, we find V_{GS} from the I_D equation for either Q_1 or Q_2,

$$I_{D1} = \frac{1}{2}\,\mu_n C_{ox}\left(\frac{W}{L}\right)_1 (V_{GS} - V_t)^2$$

$$120 = \frac{1}{2} \times 125 \times 20 \times (V_{GS} - 0.7)^2$$

$\Rightarrow V_{GS} = 1.01\ \text{V}$

$V_3 = -1.01\ \text{V}$