Homework Set 6 Solutions
EECE2412: Electronics – Spring 2013

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Problem 5.7

With $v_{GS} = v_{DS} = 5$ V the transistor operates in the saturation region for which we have $i_D = K(v_{GS} - V_{to})^2(1 + \lambda v_{DS})$. Solving for K and substituting values we obtain $K = 31.25\ \mu A/V^2$. However we have $K = (W/L)(KP/2)$. Solving for W/L and substituting values we obtain $W/L = 1.25$. Thus for $L = 2\ \mu m$, we need $W = 2.5\ \mu m$.

Repeating the calculations with $\lambda = 0.05$, we obtain $K = 25$, $W/L = 1$ and $W = 2\ \mu m$.

Problem 5.13

For a device operating in the triode region with $\lambda = 0$, we have

$$i_D = K[2(v_{GS} - V_{to})v_{DS} - v_{DS}^2]$$

Assuming that $v_{DS} << v_{GS} - V_{to}$ this becomes

$$i_D \cong K2(v_{GS} - V_{to})v_{DS}$$

Then the resistance between drain and source is given by

$$r_d = v_{DS}/i_D = \frac{1}{K2(v_{GS} - V_{to})}$$

With the device in cutoff (i.e., $v_{GS} \le V_{to}$), the drain current is zero and r_d is infinite.

Evaluating we have:

v_{GS} (V)	r_d (kΩ)
0.5	∞
1.0	∞
1.5	4
2.0	2

Problem 5.24

Many resistor values will work. In general we want to pick values such that

$$R_D I_{DQ} \cong V_{DD}/4$$

$$V_{DSQ} \cong V_{DD}/2$$

$$R_S I_{DQ} \cong V_{DD}/4$$

Thus we select $R_D = R_S = 3$ kΩ. Then we have $K = (KP/2)(W/L) = 0.2\ mA/V^2$ and $V_{GSQ} = \sqrt{I_{DQ}/K} + V_{to} = 3.236$ V. Next we compute $V_G = V_{GSQ} + R_S I_{DQ} = 6.236\ V = V_{DD}/(1 + R_1/R_2)$. Solving we find that we need $R_1/R_2 = 0.924$. Using nominal 5% tolerance values we could select $R_1 = 910$ kΩ and $R_2 = 1$ MΩ.

Problem 5.25

For a source follower we do not need a drain resistor. Thus we design for

$$V_{DSQ} = V_{DD}/2 = 6 \text{ V}$$
$$R_S I_{DSQ} = 6 \text{ V}$$

Thus we select R_S = 6.2 kΩ which is a standard 5% tolerance value. Then we have $K = (KP/2)(W/L) = 0.2 \text{ mA/V}^2$ and $V_{GSQ} = \sqrt{I_{DQ}/K} + V_{to} = 3.236$ V. Next we compute $V_G = V_{GSQ} + R_S I_{DQ} = 9.236 \text{ V} = V_{DD}/(1 + R_1/R_2)$. Solving we find that we need $R_1/R_2 = 0.2996$. Using nominal 5% tolerance values we could select R_1 = 300 kΩ and R_2 = 1 MΩ.

5 CCD

A CCD is created with square pixels measuring 7 μm $\times$ 7 μm and contains an oxide layer that is 250 nm thick with an $\epsilon = 3.8\epsilon_0$. the oxide layer has a maximum potential of 1 volt.

5.1 What is the capacitance per unit area?

$$C_{ox} = \frac{\epsilon}{t} = \frac{3.8\epsilon_0}{t} = 1.4 \text{ Farads/m}^2,$$

where t is the thickness.

5.2 What is the full well capacity?

The capacitance of a pixel is

$$C = C_{ox}A == \frac{3.8\epsilon_0}{t} \times \left(7 \times 10^{-6} \text{ m}\right)^2 = 6.6 \times 10^{-15} \text{ Farads}.$$

The charge is

$$Q = CV = \frac{3.8\epsilon_0}{t} \times \left(7 \times 10^{-6} \text{ m}\right)^2 \times 1 \text{ Volt} = 6.6 \times 10^{-15} \text{ Coulombs}.$$

The number of electrons is

$$N = \frac{Q}{q_e} = \frac{\frac{3.8\epsilon_0}{t} \times (7 \times 10^{-6} \text{ m})^2 \times 1 \text{ Volt}}{1.6 \times 10^{-19} \text{ Coulombs}} = 4.1 \times 10^4.$$

5.3 Chip Size

If you utilized these pixels to build a square, 1–megapixel CCD camera, what would its dimensions be?

One million pixels is 1000 $\times$ 1000, so there must be 1000 pixels in each direction.

$$Height = Width = 1000 * 7 \times 10^{-6} \text{ m} = 7 \text{ mm}.$$

Input 1 (V)	*Input 2 (V)*	$\mathbf{V_{out}(V)}$
0	0	5
5	0	5
0	5	5
5	5	0.4

6 Logic Gate

6.1 Truth table

Note: the last entry in the table is not 0 volts. This is acceptable as long as any circuit that utilizes V_{out} factors this in.

6.2 Current

When V_{out} is high, there is no current traveling through R_1. When V_{out} is low, the current through R_1 is

$$I_{R1} = \frac{V_1 - V_{out}}{R_1} = 0.4 \text{ mA}$$

6.3 No Connection

If V_1 and V_2 do not have a power source attached, V_{out} will be 5 volts. This would be the case in the absence of R_2 and R_3.