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Exercise 2

- 2-1. An NMOS with $W=50\mu\text{m}$ and $L=0.5\mu\text{m}$ operates in the saturated region and its layout is folded shown as Fig. 2-1. Calculate the all capacitances by using the parameters in Table2-1 and $C_{ox}=3.8\times 10^{-3}\text{ F/m}$, $V_R=0.6\text{V}$. Assume that the minimum size (lateral) of S/D region is $1.5\mu\text{m}$.

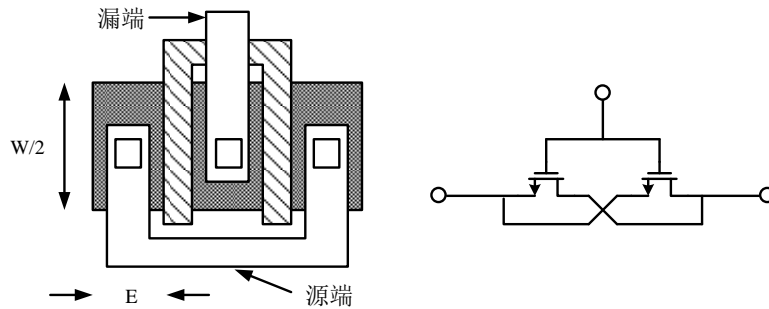


Figure 2-1

Answer:

$$C_{j0} = 0.56 \times 10^{-3} \text{ F/m}^2, C_{jsw0} = 0.35 \times 10^{-11} \text{ F/m}, m_j = 0.45, m_{jsw} = 0.2,$$

$$C_{ov} = 0.4 \times 10^{-9} \text{ F/m}, W = 50 \mu\text{m}, L = 0.5 \mu\text{m}, L_D = 0.08 \mu\text{m}, E = 1.5 \times 10^{-6} \mu\text{m},$$

$$V_R = 0.6 \text{V}, 2\Phi_F = 0.9 \text{V}, C_{ox} = 3.8 \times 10^{-3} \text{ F/m}^2, P_{SUB} = 9 \times 10^8 \text{ m}^{-3},$$

$$\epsilon_{si} = 11.9 \times 8.85 \times 10^{-12} \text{ F/m}, q = 1.6 \times 10^{-19} \text{ C}$$

$$C_j = \frac{C_{j0}}{(1 + V_R / 2\Phi_F)^{m_j}}, \quad C_{jsw} = \frac{C_{jsw0}}{(1 + V_R / 2\Phi_F)^{m_{jsw}}}$$

$$L_{eff} = L - 2L_D, \quad C_d = WL_{eff} \sqrt{q\epsilon_{si} P_{SUB} / 4\Phi_F}$$

$$C_{DB} = \frac{W}{2} EC_j + 2\left(\frac{W}{2} + E\right) C_{jsw} = 16.9 \text{ fF}$$

$$C_{SB} = 2\left(\frac{W}{2} EC_j + 2\left(\frac{W}{2} + E\right) C_{jsw}\right) = 33.7 \text{ fF}$$

$$C_{GD} = 2\left(\frac{W}{2} C_{ov}\right) = 20.0 \text{ fF}$$

$$C_{GS} = \frac{2}{3} WL_{eff} C_{ox} + WC_{ov} = 63.1 \text{ fF}$$

C_{GB} : 栅-衬底电容在三极管区和饱和区通常被忽略, 因为反型层在栅和衬底之间起了“屏蔽”的作用。换句话说, 如果栅电压发生变化, 电荷是由源和漏提供, 而不是由衬底提供。

- 2-2. There is an N-type current source, I_D is 0.5mA , and the drain-source voltage V_{DS} must less than

0.4V when it works as a current source. If the minimum output resistance is 20 K Ω , determine the length and width of the device by using the parameters in Table 2.1.

Answer:

$$\begin{cases} r_o = \frac{1}{\lambda I_D} = 20 K\Omega \\ I_D = 0.5 mA \end{cases} \Rightarrow \lambda = 0.1$$

From the table 2.1, L can be determined as L=0.5 μm .

$$L_{eff} = L - 2L_D = 0.5 \mu m - 2 \times 0.08 \mu m = 0.34 \mu m$$

Calculating W

$$I_D = \frac{1}{2} \mu_n C_{ox} \frac{W}{L_{eff}} (V_{GS} - V_{TH})^2, \quad V_{GS} - V_{TH} = V_{DSAT} = 0.4 V$$

$$\frac{W}{L_{eff}} = \frac{I_D}{\frac{1}{2} \mu_n C_{ox} (V_{GS} - V_{TH})^2} = \frac{0.5 \times 10^{-3}}{\frac{1}{2} \times 350 \times 10^{-4} \times 3.8 \times 10^{-3} \times 0.4^2} = 47$$

$$\therefore W = 47 L_{eff} = 16 \mu m$$

2-3. The layout of an n-channel MOSFET is shown in Fig.2.3. What is this device's width and length?

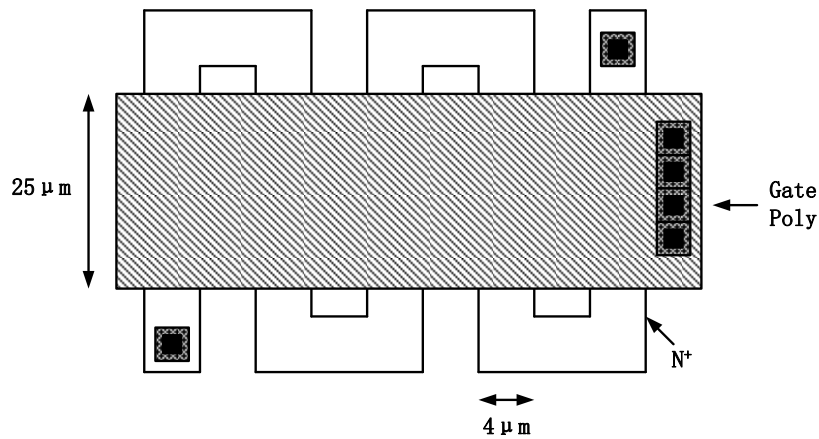


Figure 2.3

Answer:

$$Length = 5 \times 25 \mu m = 125 \mu m$$

$$Width = 4 \mu m$$

- 2-4. A “ring” MOS structure is shown in Fig. 2.4. Explain how the device operations and estimate its equivalent aspect ratio. Calculate the drain junction capacitance of the structure.

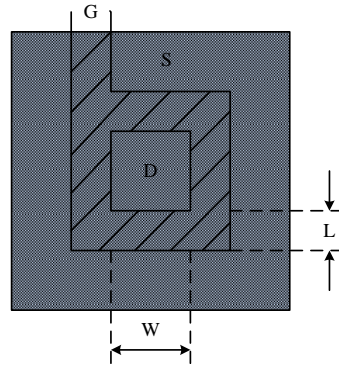


Figure 2.4

Answer:

Width/length ratio is $4W/L$

$$C_{DB} = W^2 C_j + 4WC_{jsw}$$

- 2-5. The layout of a circuit fabricated in n-well technology is shown as Fig.2.5. Give the corresponding schematic and mark the W/L sizes of each transistor. Assume $L = 2\lambda$, $\lambda = 0.4\mu m$.

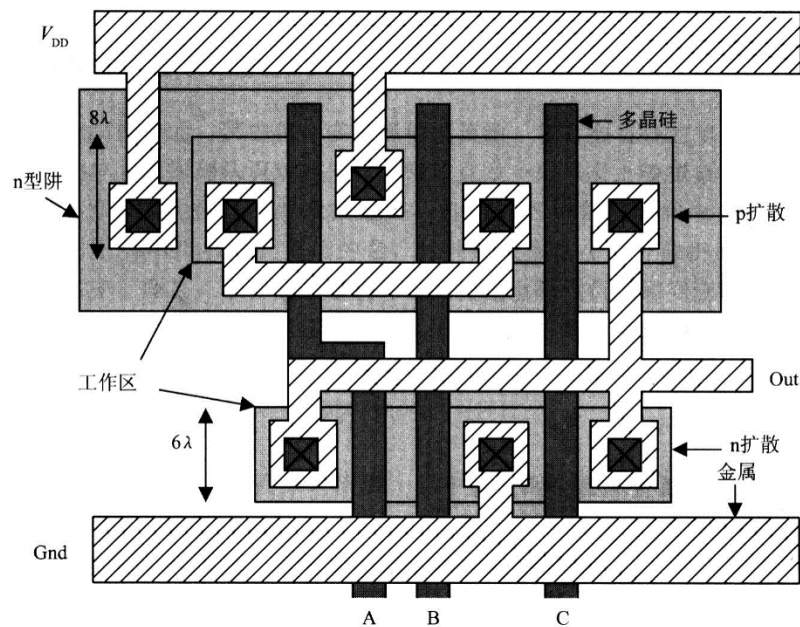
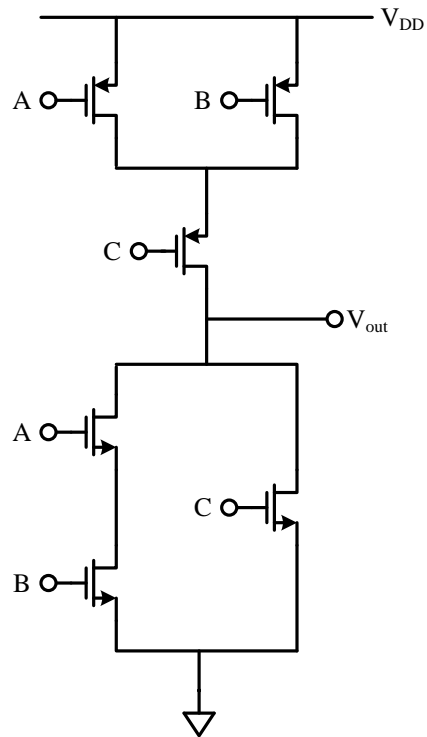


Figure 2.5

Answer:

Schematic



$$\text{Out} = \overline{AB + C}$$

W/L of N-MOSFET:

$$\frac{6\lambda}{2\lambda} = \frac{6 \times 0.4}{2 \times 0.4} = \frac{2.4}{0.8}$$

W/L of P-MOSFET:

$$\frac{8\lambda}{2\lambda} = \frac{8 \times 0.4}{2 \times 0.4} = \frac{3.2}{0.8}$$

Table 2.1

NMOS Model			
LEVEL=1	VTO=0.7	GAMMA=0.45	PHI=0.9
PSUB=9e+14	LD=0.08e-6	UO=350	LAMBDA=0.1
TOX=9e-9	PB=0.9	CJ=0.56e-3	CJSW=0.35e-11
MJ=0.45	MJSW=0.2	CGDO=0.4e-9	JS=1.0e-8
PMOS Model			
LEVEL=1	VTO=-0.8	GAMMA=0.4	PHI=0.8
PSUB=5e+14	LD=0.09e-6	UO=100	LAMBDA=0.2
TOX=9e-9	PB=0.9	CJ=0.94e-3	CJSW=0.32e-11
MJ=0.5	MJSW=0.3	CGDO=0.3e-9	JS=0.5e-8

上表给出的是 0.5 μm 工艺 level 1 MOS SPICE 模型参数的典型值，其中的参数定义如下：

VTO:	VSB=0 时的阈值电压	(单位: V)
GAMMA:	体效应系数	(单位: $\text{V}^{1/2}$)
PHI:	$2\Phi_F$	(单位: V)
TOX:	栅氧厚度	(单位: m)
NSUB:	衬底掺杂浓度	(单位: cm^{-3})
LD:	源/漏侧扩散长度	(单位: m)
UO:	沟道迁移率	(单位: $\text{cm}^2/(\text{V}\cdot\text{s})$)
LAMBDA:	沟道长度调制系数	(单位: V^{-1})
CJ:	单位面积的源/漏结电容	(单位: F/m^2)
CJSW:	单位长度的源/漏侧壁结电容	(单位: F/m)
PB:	源/漏结内建电势	(单位: V)
MJ:	CJ 公式中的幂指数	(无单位)
MJSW:	CJSW 等式中的幂指数	(无单位)
CGDO:	单位宽度的栅/漏交叠电容	(单位: F/m)
CGSO:	单位宽度的栅/源交叠电容	(单位: F/m)
JS:	源/漏结单位面积的漏电流	(单位: A/m^2)