

EE3800 Test 2

Name: _____

Student ID#: _____

Question 1 (40 marks)

- (a) What are the advantages of channel length downsizing?
- (b) Explain from the (i) device structure and (ii) circuit applications points of view that the CMOS device is the more favorable structure for downsizing and upscaling than BJT.
- (c) Explain the short-channel effects of the MOS transistor. How can the effects be overcome?

ANSWER:

- (a) Give any 5 points. Each valid point 3 marks
- (b) Give any 5 points. Each valid point 3 marks.
- (c) Give any 5 points (short-channel effects or method to overcome)
Each valid point 2 marks.

Q. 2

ANSWER:

$$(a) \quad V_{bi} = \frac{KT}{q} \ln \frac{N_A N_D}{n_i}$$

$$= 0.0258 \ln \frac{10^{15} \times 10^{19}}{(1.5 \times 10^{10})^2}$$

$$\approx 0.811 \text{ V}$$

(5 marks)

$$(b) \quad \text{Junction bias } V_{SB} = V_{GS} - V_T = 1 - 0.5 = 0.5 \text{ V}$$

$$W_S = \sqrt{\frac{2\epsilon_{Si}}{q} \left(\frac{1}{N_A} + \frac{1}{N_D} \right) (V_{bi} - V_{SB})}$$

$$= \sqrt{\frac{2 \times 3.5 \times 10^{-13}}{1.602 \times 10^{-19}} \left(\frac{1}{10^{15}} + \frac{1}{10^{19}} \right) (0.811 - 0.5)}$$

$$= 0.3685 \times 10^{-5} \text{ cm} = 0.3685 \mu\text{m}$$

(8 marks)

$$(c) (i) \text{ Drain junction bias (reverse)} = V_{DB} = V_{DS} - (V_G - V_T) = 0.5$$

$$W_D = \sqrt{\frac{2\epsilon_{Si}}{q} \left(\frac{1}{N_A} + \frac{1}{N_D} \right) (V_{bi} + V_{DB})}$$

$$= 0.7585 \mu\text{m}$$

(7 marks)

$$(ii) \text{ Drain reverse bias } V_{DB} = 3.5 \text{ V}$$

$$W_D = 1.3725 \mu\text{m}$$

(7 marks)

$$(d) (i) \text{ Effective channel length}$$

$$L_{\text{eff}} = 5 - 0.3685 - 0.7585 = 3.873 \mu\text{m}$$

$$C_{ox} = \frac{\epsilon_{ox}}{t_{ox}} = 1.75 \times 10^{-7} \text{ F/cm}^2$$

$$I_D = \frac{\mu_n C_{ox} W}{2 L_{\text{eff}}} (V_{GS} - V_T)^2 = 39.53 \mu\text{A}$$

(6 marks)

$$(ii) \quad L_{eff} = 3.259 \mu m$$

$$I_D = 46.99 \mu A$$

(6 marks)

$$(e) \quad I_D = \frac{\mu_n C_{ox} W}{2L} (V_{GS} - V_T)^2 (1 + \lambda V_{DS})$$

$$= \frac{\mu_n C_{ox} W}{2L_{eff}} (V_{GS} - V_T)^2$$

$$1 + \lambda V_{DS} = \frac{L}{L_{eff}}$$

$$\lambda = \left(\frac{L}{L_{eff}} - 1 \right) / V_{DS}$$

(8 marks)

$$(i) \quad \lambda = 0.291 \text{ V}^{-1}$$

(4 marks)

$$(ii) \quad \lambda = 0.1336 \text{ V}^{-1}$$

(4 marks)

(f) For $L = 1 \mu m$, under the bias given in (c) would cause the depletion region of drain extended to the source region, the barrier between the drain and source is punch-through. (The given doping conditions are thus not suitable for $L = 1 \mu m$. As the channel length decreases, the channel doping to minimize the depletion region.) Under this situation, the drain current is governed by the reverse saturation current of drain junction.

5 + 10 (bonus)