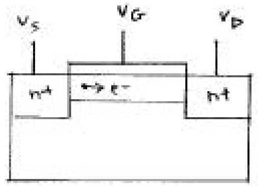
10. (a) What do the letters NMOSFET stand for? Sketch the cross section of an enhancement NMOSFET, describe the movement of electrons, the threshold voltage, and explain very briefly the operation of the NMOSFET. (12)

N-channel Metal Oxide Semiconductor
Field Effect Transistor

3




$V_G \geq V_T$

channel forms ($e^-$ attracted)

I flow

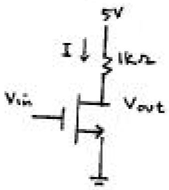
I control by $V_G$

9

(b) In the NMOSFET circuit, $V_T = 1V$, $K = 1mA/V^2$. Find the current I and the voltage Vout when (i) Vin = 0.5V, (ii) Vin = 2V, and (iii) Vin = 4V. Show the reasons for your methods. Estimate also the value of $r_{on}$ at $V_{GS} = 3.5V$.

Given that $I_{DS} = 2K[(V_{GS} - V_T)V_{DS} - \frac{V_{DS}^2}{2}]$ at Triode region,

$I_{DS} = K(V_{GS} - V_T)^2$ at saturation region, and $\frac{1}{r_{on}} = \frac{\partial I_{DS}}{\partial V_{DS}}$ at $V_{DS} = 0$. (34)




(i) $V_{in} = 0.5\,V$

$V_{GS} < V_T$

$\therefore I = 0$

$V_{out} = 5\,V$

5

$\therefore I = K(V_{GS} - V_T)^2$

$= 1m(2-1)^2$

$= 1mA$

$\therefore V_{out} = 5 - I(1K) = 4V$

$V_{DS} > V_{GS} - V_T$ $\therefore$ saturation confirmed

$4 > 2 - 1$

10

(iii) $V_{in} = 4V$ assume triode

$\therefore I = 2K[(V_{GS} - V_T)V_{DS} - \frac{V_{DS}^2}{2}] = \frac{5 - V_{DS}}{1k}$

$\therefore 2(1m)[(4-1)V_D - \frac{V_D^2}{2}] = \frac{5 - V_D}{1k}$

$\therefore 2(3V_D - \frac{V_D^2}{2}) = 5 - V_D$

$\therefore V_D^2 - 7V_D + 5 = 0$

$V_D = \frac{7 \pm \sqrt{7^2 - 4(5)}}{2}$

$V_D = \frac{7 \pm 5.38}{2} = 6.19$ or $0.81V$

$\therefore V_{out} = 0.81\,V$

$V_{DS} < V_{GS} - V_T$ $\therefore$ triode confirmed

$0.81 < 4 - 1$

13

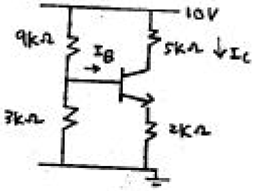
$r_{on} = \frac{\partial V_{DS}}{\partial I_{DS}} = \frac{1}{2K(V_{GS} - V_T)}$

$= \frac{1}{2(1m)(3.5-1)}$

$= 200\,\Omega$

6

11. (a) Explain briefly why the circuit can have stable $I_C$.
(b) In the BJT circuit, find $I_B$.
(c) Find the operating mode of BJT and show your reasons.
For the BJT, given $V_{BE} = 0.7V$ and $\beta = 100$. (29)

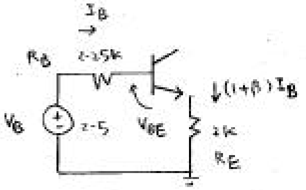



(a) $I_c \uparrow \quad V_E \uparrow \quad V_{BE} \downarrow$

$I_B \downarrow \quad I_c \downarrow$

(b) $V_B = 10 \dfrac{3k}{9k + 3k} = 2.5\,V$

$R_B = 3k \| 9k = \frac{27}{12} k = 2.25\,k\Omega$




$\therefore I_B = \dfrac{V_B - V_{BE}}{R_B + (1+\beta) R_E}$

$= \dfrac{2.5 - 0.7}{2.25k + (1+100)2k}$

$= \dfrac{1.8}{204.25k} = 8.8\,\mu A$

(c) If active, $I_c = \beta I_B$

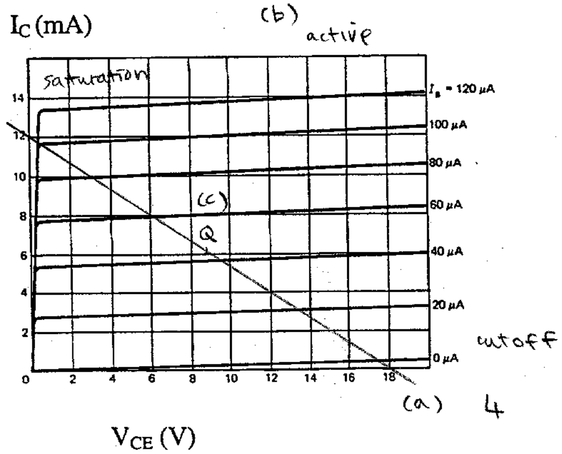
$= 100\,(8.8\mu) = 0.88\,mA$

$\therefore I_c\, 5k + I_E\, 2k$

$= 6.2V < 10V$

$\therefore$ BJT active

12. The BJT in the circuit has the output characteristic curves as shown.
(a) Sketch the load line $V_{CC} = I_C R_C + V_{CE}$. (b) Show roughly on the output curves the three operating regions of the BJT. (c) Locate the Q-point on the loadline if Vin = 1.15V.
(d) Estimate β and α for the BJT. (e) Sketch the AC equivalent circuit and find the voltage gain $A_V$ (= ΔVout /ΔVin) of the circuit.
Given that for the BJT, $V_{BE} = 0.7V$, $r_\pi = 1\,k\Omega$, ro = ∞. (30)

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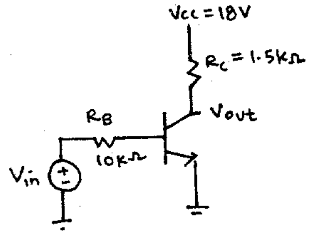
4




(c) $V_{in} = 1.15\,V$

$I_B = \dfrac{1.15 - 0.7}{10k} = 45\,\mu A$

4

(d) $\beta \sim \dfrac{I_c}{I_B} \sim \dfrac{14mA}{120\mu} \sim 120$ 3

$\alpha = \dfrac{\beta}{1+\beta} \sim \dfrac{120}{121}$ 3