Quiz #1 - Friday, Aug. 27, 9am - 9:25am

Todays Lecture

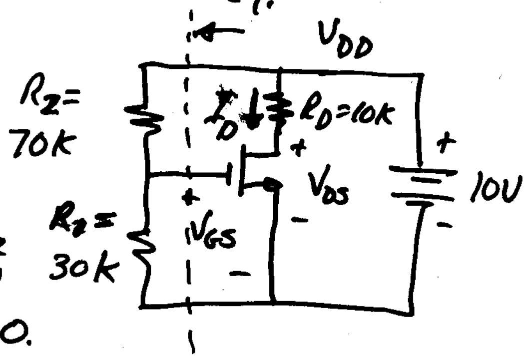
- MOSFET Example 1
- MOSFET Example 2
- MOSFET Capacitances
- BJT introduction
- BJT Example 1
- BJT Example 2

Homework due in class or by 4pm to Marge Boehme VanLeer E274.

Nola Li 9-12 Thurs.

MOSFET Example 1

Find the dc operating point for the NMOS transistor shown assuming $K_N' = 25\mu A/V^2$, $\frac{W}{L} = 10$, $V_{TN} = 1V$ and $\lambda = 0$.

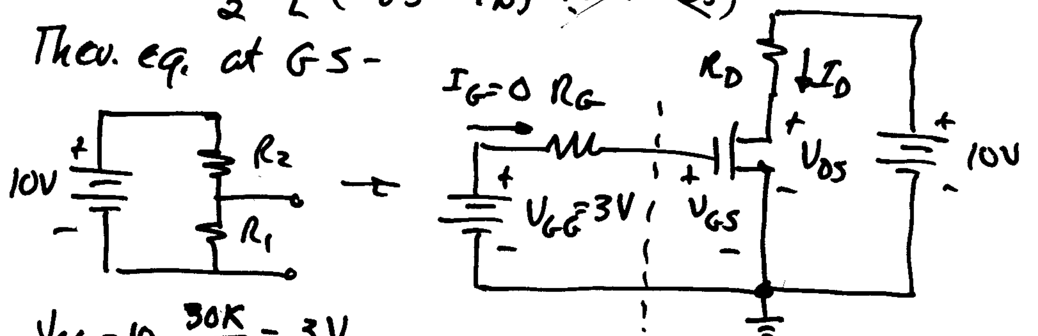


Solution

Assume the MOSFET is saturated

$\therefore i_D = \frac{K_N'}{2}\frac{W}{L}(v_{GS}-V_{TN})^2 \cancel{(1+\lambda v_{DS})}$

Thev. eq. at GS -



$V_{GG} = 10\frac{30K}{100K} = 3V$

$R_G = 30K \| 100K = 21K$

$\therefore \underline{\underline{V_{GS} = 3V}} \rightarrow I_D = \frac{250\mu A}{2\ V^2}(3-1)^2$

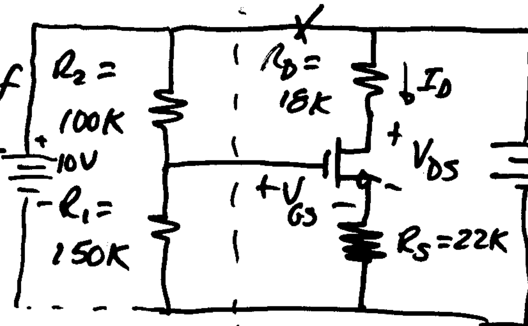
$I_D = \underline{\underline{500\mu A}}$

$V_{DS} = 10V - I_D R_D = 10V - 5V = \underline{\underline{5V}}$

The MOSFET is sat. if $V_{DS} \geq V_{GS} - V_T \rightarrow 5V \overset{?}{\geq} 2$ Yes

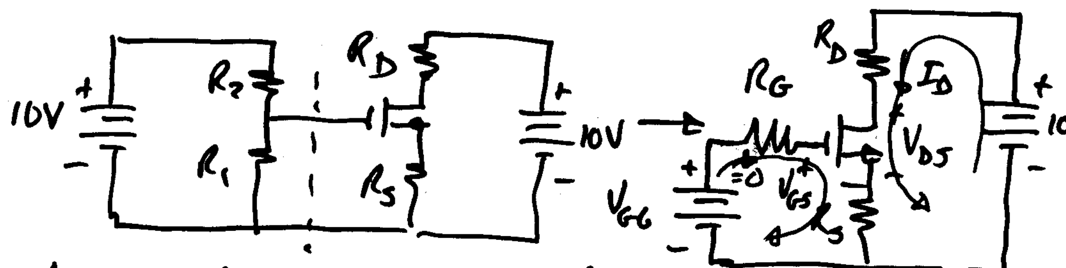
MOSFET Example 2

Using the parameters of Ex. 1, find the Q point.



Solution

Simplify by Thev. concept -



Assume the MOSFET is saturated -

GS - loop:

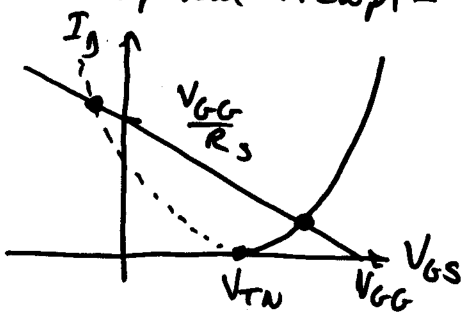
$$V_{GG} = V_{GS} + I_D R_S \quad \& \quad I_D = \frac{K_N'}{2}\frac{W}{L}(V_{GS} - V_{TN})^2$$

$$V_{GG} = V_{GS} + \frac{K_N' R_S}{2}\frac{W}{L}(V_{GS} - V_{TN})^2$$

Quadratic: $V_{GS}^2 - 1.636 V_{GS} - 1.182 = 0$

$V_{GS} = 0.8182 \pm 1.361 = \underline{2.179V}$

Graphical viewpt -



$I_D = \frac{250}{2}(2.179 - 1)^2 = \underline{174 \mu A}$

$V_{DS} = 10V - I_D(R_D + R_S)$

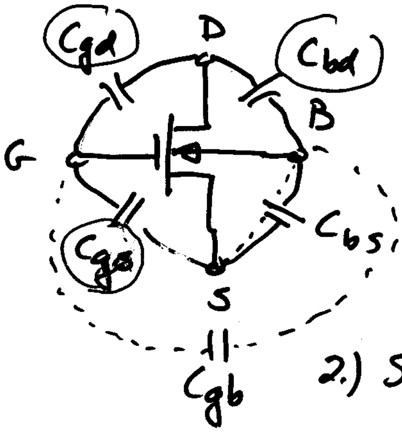
$= 10V - 0.174(40K)$

$V_{DS} = 10 - 6.96 = 3.\underline{04}V$

$V_{GS} - V_T = 2.179V - 1 = 1.179V$

$\therefore$ MOSFET is sat.

MOSFET Capacitances



Assume $V_{BS} = 0$ and $C_{gb} \approx 0$

1.) Active, linear, triode, ohmic

$v_{DS} < v_{GS} - V_{TN}$

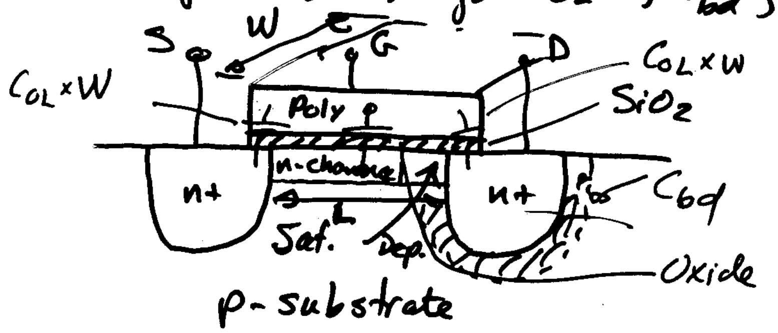
$C_{gs} = C_{OL} W + \frac{1}{2} C_{ox} WL = C_{gd}$, C_{bd}

2.) Saturation $v_{DS} > v_{GS} - V_{TN}$

$C_{gs} = C_{OL} W + \frac{2}{3} C_{ox} WL$, $C_{gd} = C_{OL} W$, C_{bd}

3.) Cutoff $v_{GS} < V_T$

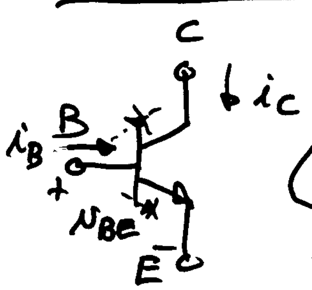
$C_{gs} = C_{OL} W$, $C_{gd} = C_{OL} W$, C_{bd}, $C_{gb} = C_{ox} WL$



$C_{ox} = F/\text{Area}^2$
$= 1 fF/\mu m^2$

$$C_{bd} = \frac{C_{bd0}}{\sqrt{1 - \frac{v_{bd}}{\Phi_B}}}$$

Bipolar Junction Transistor



Regions of operation –

Region	BE	BC
Forward active	Fwd.	Rev.
Saturation	Fwd	Fwd
Reverse active	Rev.	Fwd.
Cutoff	Rev.	Rev.

Models -

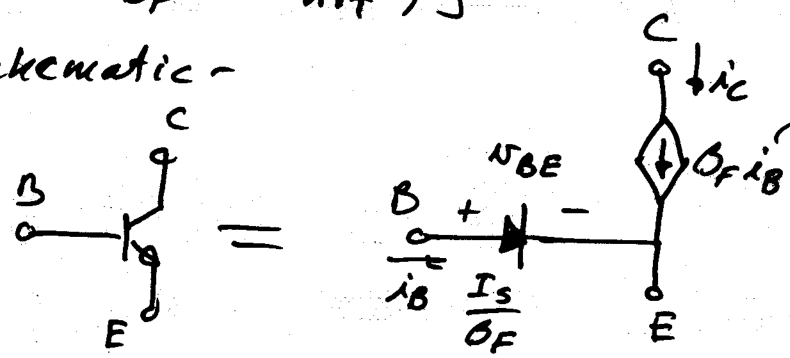
Equations - Forward active region.

$$i_C = \beta_F i_B$$

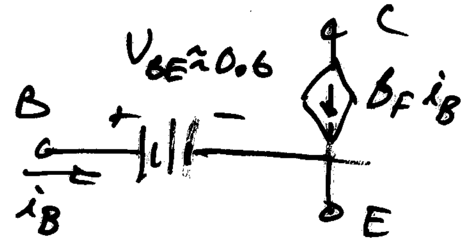
$$i_B = \frac{I_S}{\beta_F}\left(\exp \frac{v_{BE}}{nV_T}\right)$$

$$\Big\} \quad i_C = I_S \exp\left(\frac{v_{BE}}{n V_T}\right)$$

Schematic -

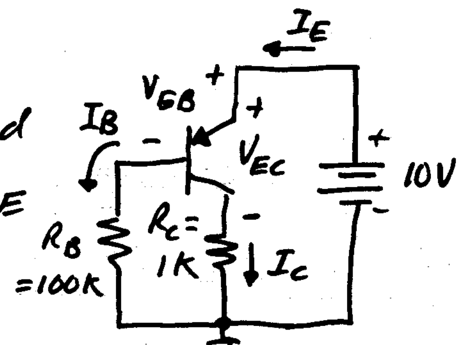


If i_B is mostly determined externally, then



BJT Example 1

If $\beta_F = 50$, find I_C, V_{EC}, V_{EB}, I_E and I_B



Voltage loop: $10V = V_{EB} + I_B R_B \rightarrow I_B = \frac{10V - V_{EB}}{R_B}$

Since we know that $10V >> V_{EB}$ we can use the model where $V_{EB} \approx 0.7V$.

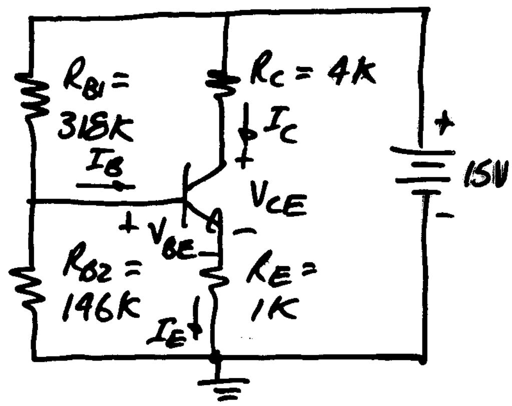
$\therefore I_B = \frac{10-0.7}{100K} = \underline{\underline{93\mu A}}$ $\quad I_C = \beta_F I_B = \underline{\underline{4.65 mA}}$

$I_E = I_B + I_C = \underline{\underline{4.74 mA}}$, $V_{EB} \approx 0.7V$, $V_C = I_C R_C = 4.65V$

$V_{EC} = V_E - V_C = \underline{\underline{5.35V}}$

BJT Example 2

Find the quiescent point if $\beta_F = 100$ and $V_{BEQ} = 0.65V$.

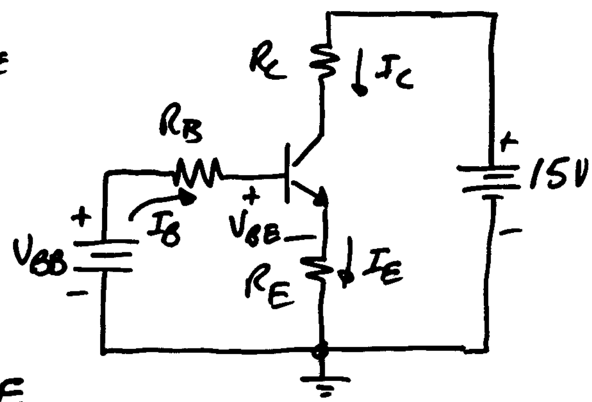


Solution

1.) $V_{TH} = V_{BB} = 15V \frac{146}{318+146} = 4.72V$

2.) $R_{TH} = R_B = 318K // 146K = 100K$

∴ The circuit can be rewritten as,



3.) Loop eq. around BE

$$V_{BB} = I_B R_B + V_{BE} + I_E R_E = V_{BE} + I_B R_B + (1+\beta_F) I_B R_E$$

$$\therefore I_B = \frac{V_{BB} - V_{BE}}{R_B + (1+\beta_F) R_E} = \frac{4.72 - 0.65}{100K + (101)1K} = \underline{\underline{20\mu A}}$$

4.) $I_C = 100 \, I_B = \underline{\underline{2mA}}$

5.) $I_E = I_C + I_B = \underline{\underline{2.02 \, mA}}$

6.) $V_{CE} = 15V - I_C R_C - I_E R_E = 15 - (2)(4) - (2.02)(1)$

$\underline{\underline{V_{CE} = 4.88V}}$