## Topics

- Second MOSFET Example
- Bipolar Junction Transistors
- Approximate BJT Large Signal Models
- BJT Example 1
- BJT Example 2

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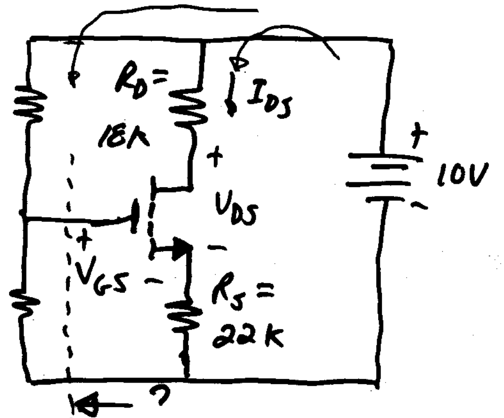
Remember: Quiz #1 a week from now.

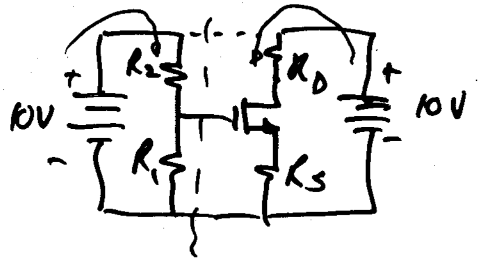
## Second MOSFET Example

Find operating point if $K_N' = 25\mu A/V^2$, $\frac{W}{L} = 10$, $V_{TN} = 1V$, and $\lambda = 0$.

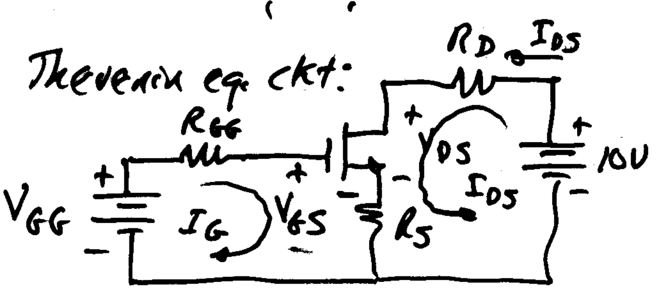
$$i_D = \frac{1}{2}\frac{K_N'}{W}(v_{GS}-V_T)^2(1+\overset{0}{\cancel{\lambda}}\, v_{DS})$$



### Solution



Thevenin eq. ckt:



$V_{GG} = 10V \times \frac{150k}{250k} = 6V$

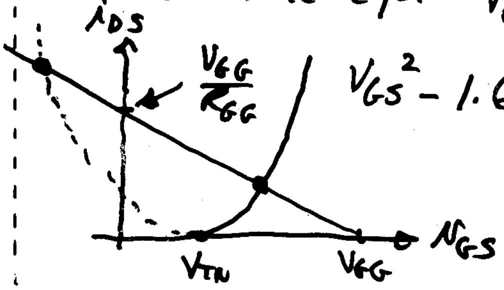
$K_N = K_N' \frac{W}{L}$

$R_{GG} = R_1 \| R_2 = 60k$

G-S loop eq: $V_{GG} = V_{GS} + I_{DS}R_S$

Large Sig. Model for sat.: $I_{DS} = \frac{K_N}{2}(V_{GS}-V_T)^2$

Combine eqs. $V_{GG} = V_{GS} + \frac{K_n R_S}{2}(V_{GS}-V_{TN})^2$



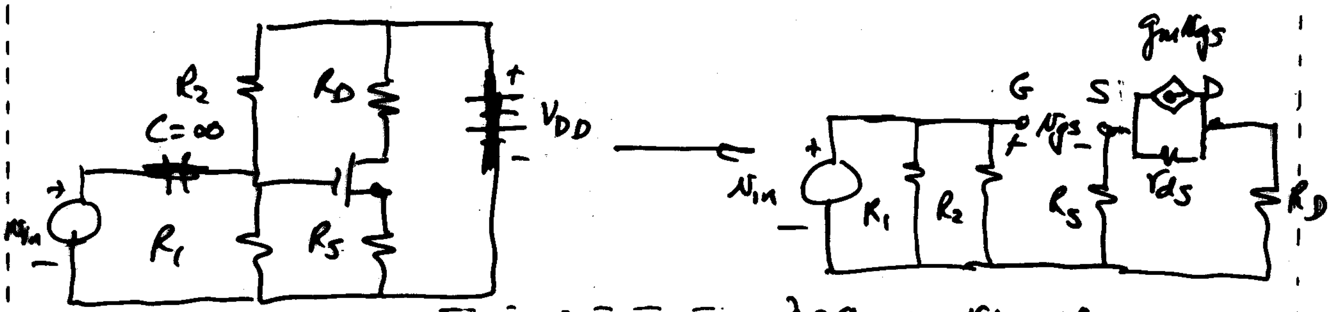
$V_{GS}^2 - 1.636V_{GS} - 1.182 = 0$

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

$I_{DS} = \underline{\underline{174\mu A}} \rightarrow V_{DS} = 10 - (174\mu A)18k$

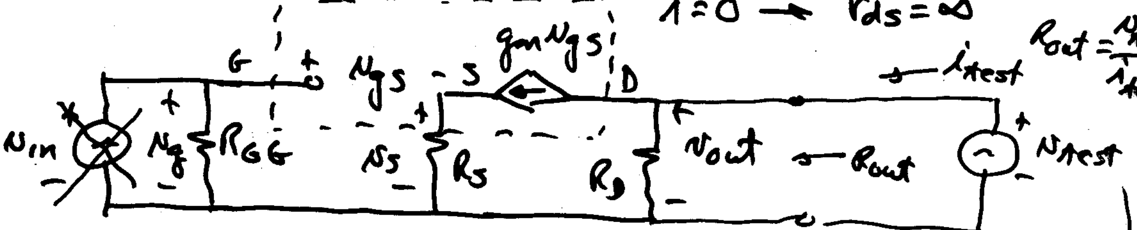
$V_{DS} = 6.868V$ $V_{GS} - V_T = 1.179V$

## Small-signal MOSFET Model of Previous Example



$\lambda = 0 \rightarrow r_{ds} = \infty$

$R_{out} = \frac{v_{test}}{i_{test}}$



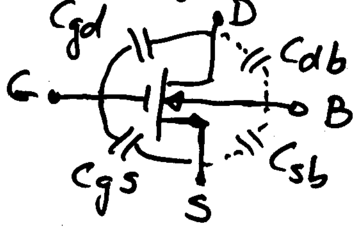
$\frac{v_{out}}{v_{in}} = ?$ $\quad \frac{v_{out}}{v_{in}} = \left(\frac{v_{out}}{v_{gs}}\right)\left(\frac{v_{gs}}{v_{in}}\right) = \left(-g_m R_D\right)\left(\frac{1}{1+g_m R_S}\right)$

$v_{gs} = v_g - v_s = v_{in} - g_m R_S v_{gs} \rightarrow v_{gs}(1+g_m R_S) = v_{in}$

$R_{out} = \frac{v_{test}}{i_{test}}\Bigg|_{v_{in}=0}$

## MOSFET

Capacitances - $C_{gs}$, $C_{gd}$, $C_{db}$, $C_{sb} \rightarrow 0$ if $V_{SB}=0$



Linear: $v_{DS} < v_{GS} - V_T$ $\quad C_{gs} = C_{OL}W + 0.5C_{ox}WL$, $C_{gd} = C_{OL}W + 0.5C_{ox}WL$, $C_{db} = 0$

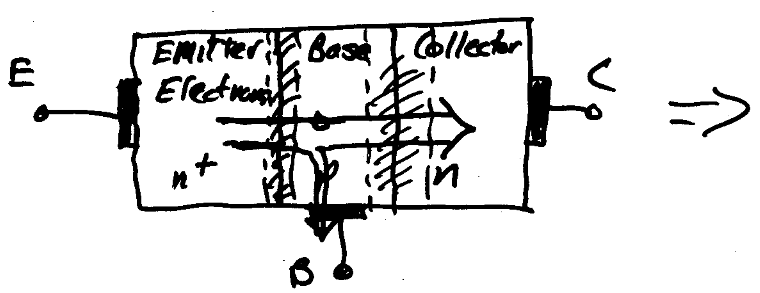
Saturation: $v_{DS} > v_{GS} - V_T$ $\quad C_{gs} = C_{OL}W + \frac{2}{3}C_{ox}W$, $C_{gd} = C_{OL}W$, $C_{db} = 0$

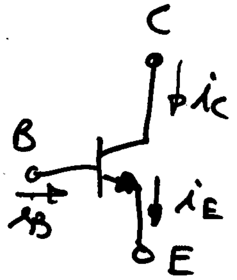
Cutoff: $v_{GS} < V_T$ $\quad C_{gs} = C_{OL}W$, $C_{gd} = C_{OL}W$, $C_{gb} = C_{ox}WL$

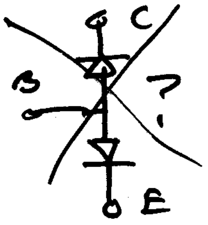
$C_{OL}$ = overlap capacitance between gate & drain/source

# BIPOLAR JUNCTION TRANSISTORS

## Physical Picture:







## Active Forward Region of operation:

BE is forward-biased

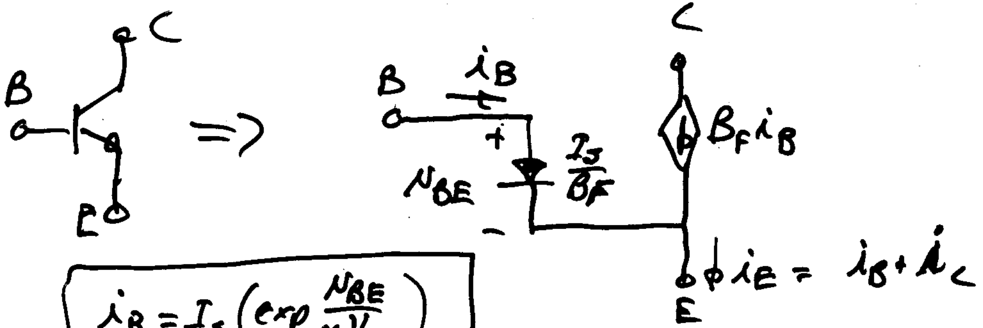
BC is reverse-biased

$i_C = \beta_F i_b$

$i_C = \alpha_F i_E$

## Large Signal Model:

(Forward-active region)

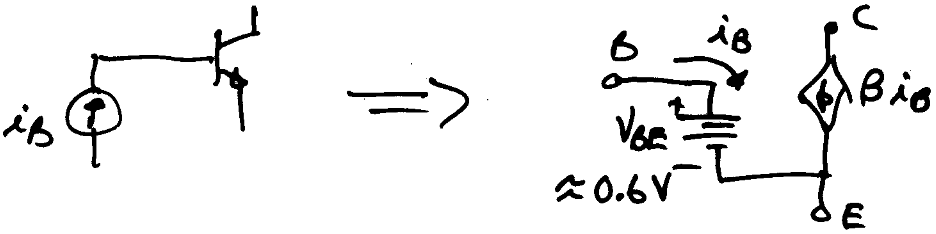


$$\boxed{i_B = \frac{I_S}{\beta_F}\left(\exp\frac{v_{BE}}{n V_T}\right)}$$

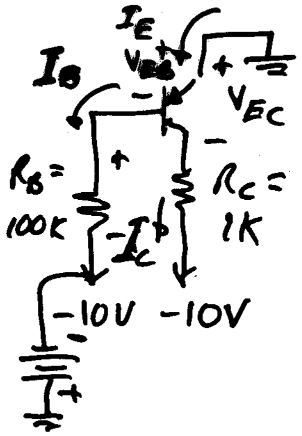
$$\boxed{i_C = \beta_F i_B = I_S \exp\left(\frac{v_{BE}}{V_T}\right)}$$ (n=1)

## Simplification:

Current $i_B$ is determined externally



## Example 1



If $\beta_F = 50$, find $I_c$, $V_{EC}$, $V_{EB}$, $I_E$, & $I_B$

$+10V = I_B R_B + V_{EB}$

$I_B = \frac{10 - V_{EB}}{R_B}$

$I_B = \frac{10 - 0.7}{100K} = \underline{\underline{93\mu A}}$

$\xcancel{I_B \approx \frac{10}{100K} = 100\mu A}$

$\underline{\underline{V_{EB} \cong 0.7}}$

$I_c = 50 \cdot 93\mu A = \underline{\underline{4.65\,mA}}$

$I_E = I_B + I_c = \underline{\underline{4.74mA}}$

$V_c = -10 + I_c R_c = \underline{\underline{-5.35V}}$ $\quad \underline{\underline{V_B = -0.7V}}$ $\quad \underline{\underline{V_E = 0}}$

$V_{EC} = 5.35V$