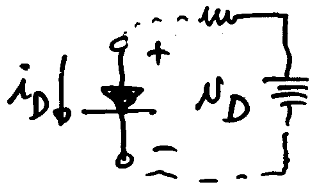
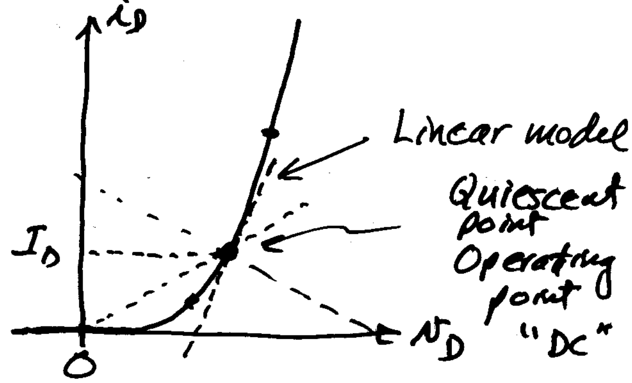
Topics –
- Small-signal model of the diode
- Diode example
- MOSFET – Physical
- MOSFET Large signal model
- MOSFET Example 1 and 2

More Office Hours:
Richard Tarbell
10–12 MW
1–2:30 TTh
Prof. Moad's help office area, (4th floor) Rm. 448

Small-signal Model

The s.s. model is a LINEAR model of a nonlinear device

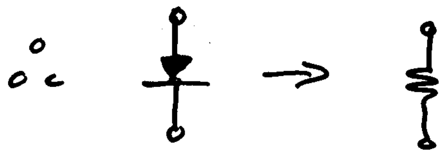




$$\frac{\partial i_D}{\partial v_D} = g_d = \frac{1}{r_d}$$

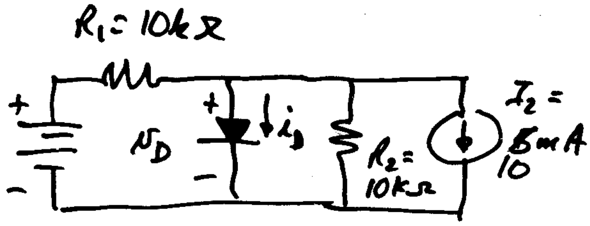
$$i_D \cong I_s \exp\left(\frac{v_D}{nV_T}\right) - \cancel{I_s}$$

$$\frac{\partial i_D}{\partial v_D} = \frac{I_s}{nV_t}\exp\left(\frac{v_D}{nV_t}\right) = \frac{I_D}{nV_T} = g_d = \frac{1}{r_d}$$



$$r_d = \frac{1}{g_d}$$

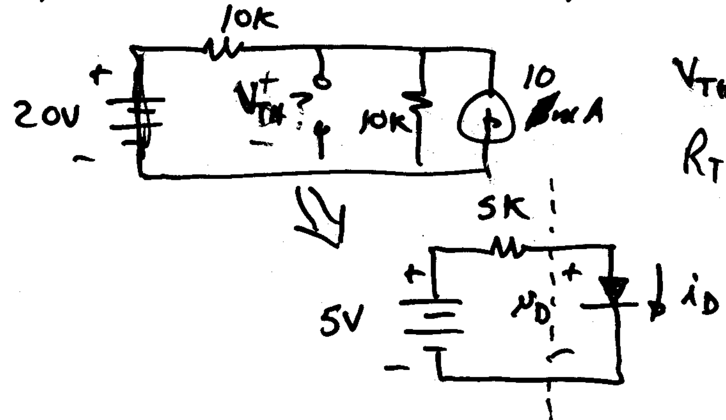
Diode Example



a.) Find the dc operating point if $V_T = 0.025V$, $n = 1$ and $I_S = 100fA$.

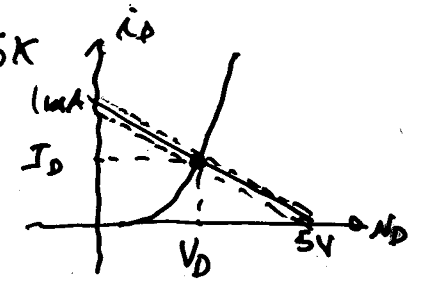
b.) If the 20V voltage source has a peak-peak sinusoidal signal of 10mV placed in series with it, find the p-p value of v_d and i_d of the diode.

a.) Find the Thevenin eq. seen from diode



$V_{TH} = 10V - 1mA \cdot 5K = 5V$

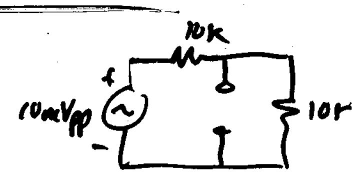
$R_{TH} = 5K$



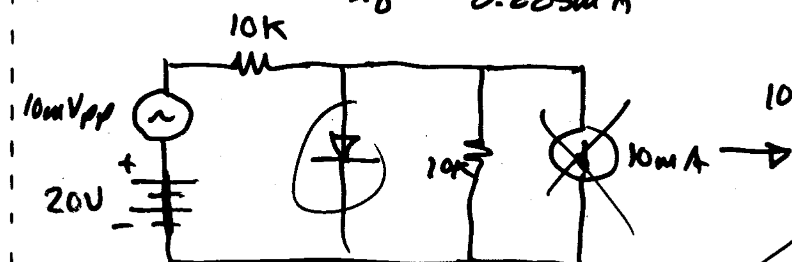
Guess at v_D	$i_D = \frac{5V - v_D}{5K}$	$i_D = I_S\left[\exp\left(\frac{v_D}{V_T}\right) - 1\right]$
0.6	0.88 mA	2.331 mA
0.57	0.886 mA	0.798 mA
⋮	⋮	⋮
0.5726	0.88548 mA	0.88528 mA

$\therefore$ $V_D = 0.573V$ + $I_D = 0.885mA$

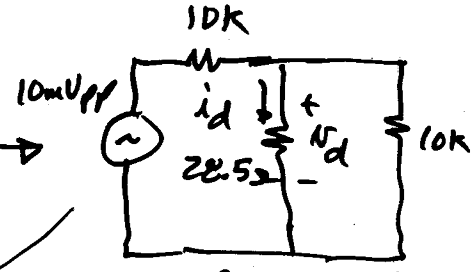
b.) S.S. model of diode.



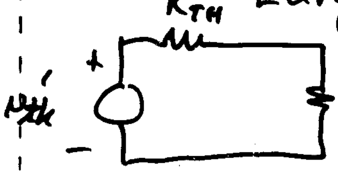
$r_d = \frac{V_T}{I_D} = \frac{25mV}{0.885mA} = 28.5\Omega$

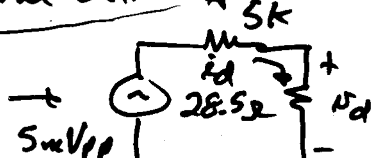


Large-signal ckt.



Small-signal ckt.



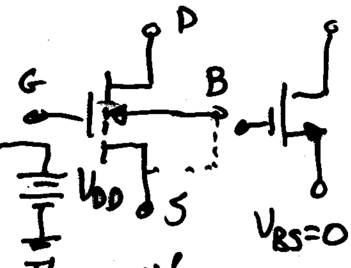


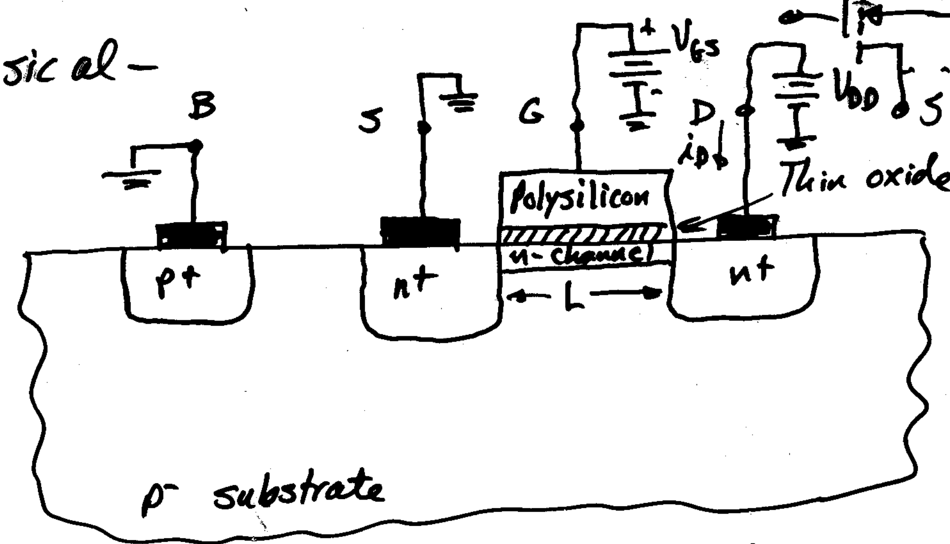
$v_d = \frac{28.5}{5028.5} \times 5mV_{pp}$

$i_d = \frac{5mV_{pp}}{5028.5}$

MOSFET

Physical -





Enhancement - Threshold is >0 for NMOS (V_T)
Depletion - Threshold is <0 for NMOS (V_T)

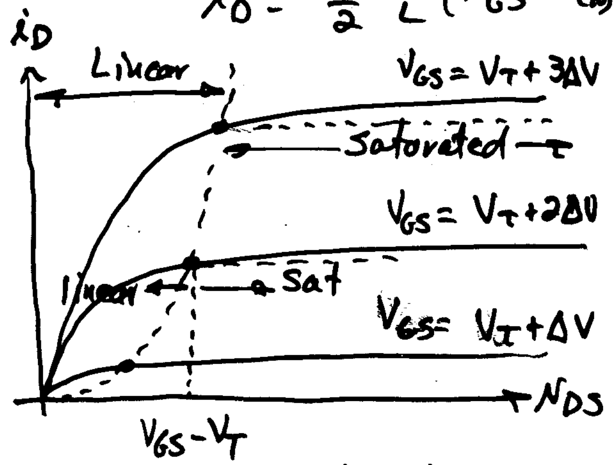
Model -

1.) Linear region - $i_D = K_n' \frac{W}{L}\left(v_{GS} - V_{TN} - \frac{v_{DS}}{2}\right) v_{DS} (1+\lambda v_{DS})$

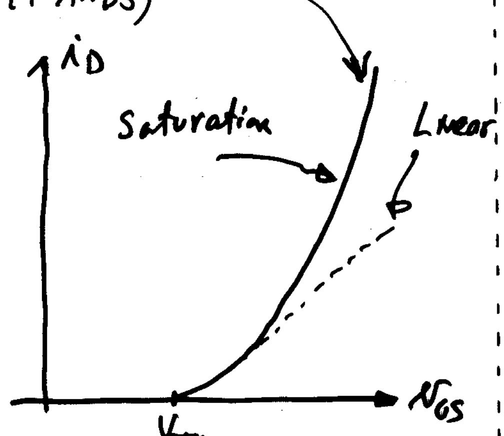
$$v_{GS} - V_{TN} < v_{DS}$$

2.) Saturated region ($v_{GS} - V_{TN} > v_{DS}$)

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



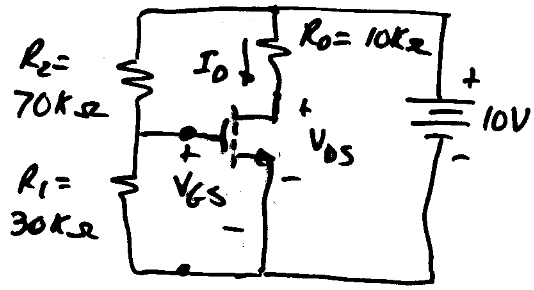
Output Characteristics



Transconductance Curve

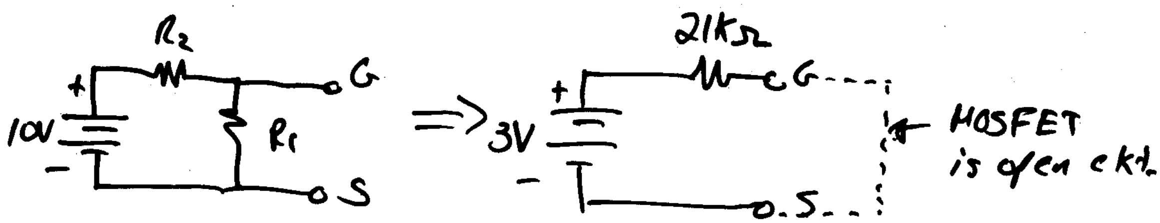
MOSFET Example

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



Solution

Thev. eq. circuit from G-S.



$\therefore V_{GS} = 3V$

Assume the MOSFET is sat.

$$I_D = \frac{K_n'}{2}\frac{W}{L}(V_{GS} - V_{TN})^2 = 500\mu A \Rightarrow V_{DS} = 5V$$

Check to make sure $V_{DS} > V_{GS} - V_T$ OKAY