Wed 9 Nov 2016

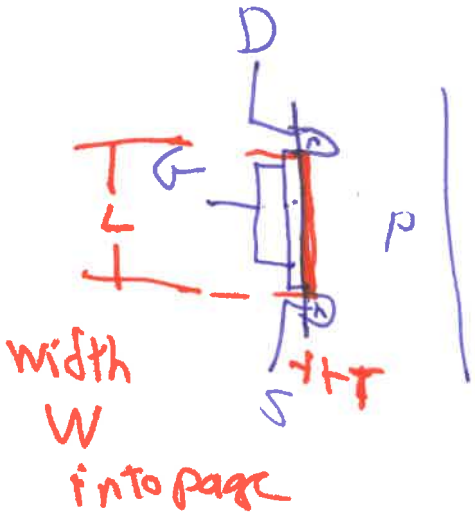
Terminal Characteristics

$i_D = K[2(V_{GS}-V_{TH})V_{DS} - V_{DS}^2]$ Triode

$i_D = K(V_{GS}-V_{TH})^2$ saturation

Bounding $i_D = K V_{DS}^2$

or $V_D = V_{GS} - V_{TH}$



$K = \frac{W}{L}\frac{1}{2}\mu_n C_{ox}$

$1500 \frac{cm^2}{Vs}$

$1500 \frac{cm/s}{V/cm}$

$K = \frac{W}{L}\frac{KP}{2}$

$KP = \mu_n C_{ox}$

$= 50\,\mu A/V^2$

Capacitance

$C_{ox} = \frac{50\,\mu A/V^2 \quad Vs}{1500\ cm^2} = 3.3\times10^{-8}\ \frac{coul}{V\,cm^2}$

$= \frac{33\,nF}{cm^2}$

$C = C_{ox} WL$

5um × 5um

$Q = CV = 33\frac{nf}{cm^2}(5\times10^{-4}cm)^2\,1V$

$= 8\times10^{-15}$ coulombs.

$$\frac{8 \times 10^{-15}\ \text{coul}}{1.6 \times 10^{-19}\ \frac{\text{coul}}{\text{electron}}} = 52\text{K electrons}$$

$$K = \frac{W}{L}\ \frac{KP}{2} \qquad KP = \mu_n C_{ox} \approx 50\mu A/V^2$$

$200nm < L < 10\mu m$

$500nm < W < 500\mu m$

use $\frac{W}{L}$ to control K

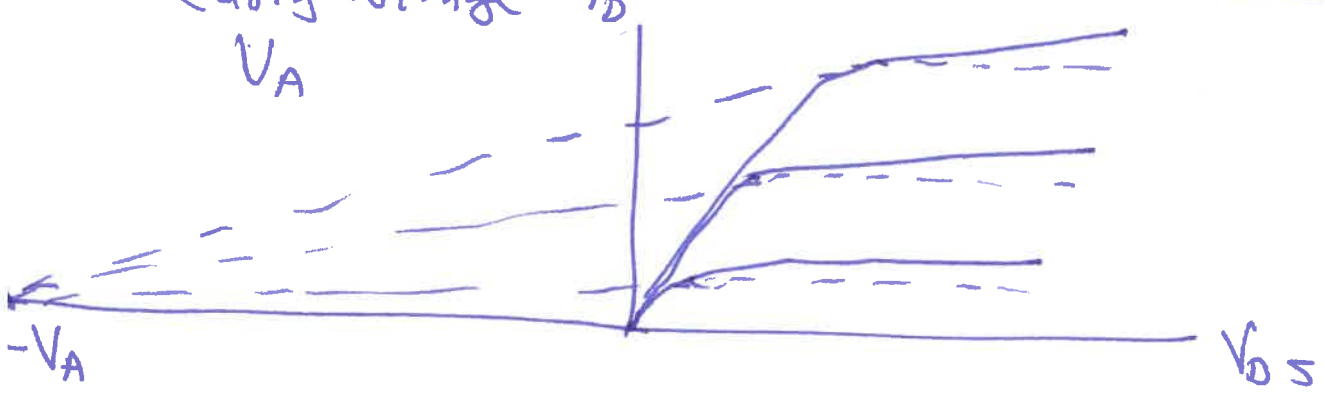
W to carry enough current

WL to get C

Example $\frac{W}{L} = 10$ $\quad K = 250\mu A/V^2$

$V_{GS} - V_{TO}$	$i_D = K(V_{GS} - V_{TO})^2$
1 V	250μA
2 V	1.0 mA
3 V	2.25mA
4 V	4.00 mA

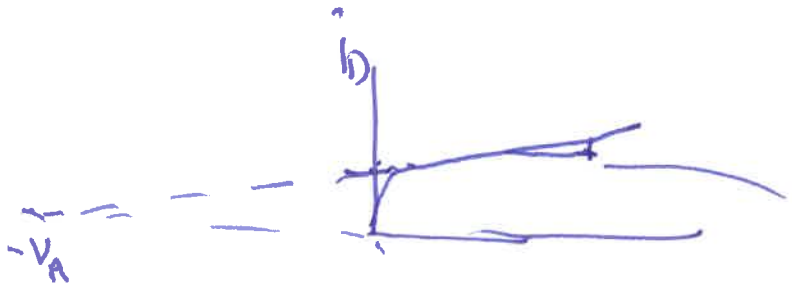
Early voltage V_A



"small" correction to the saturation Eqn.

$$i_D = K(V_{GS} - V_{TO})^2 (1 + \lambda V_{DS})$$

↑ Resistor

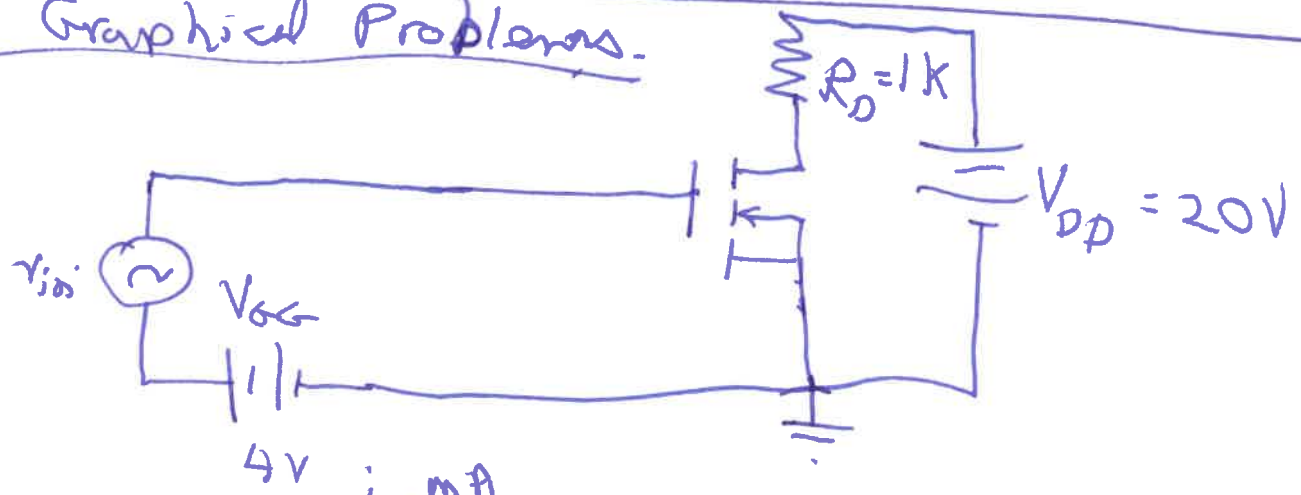


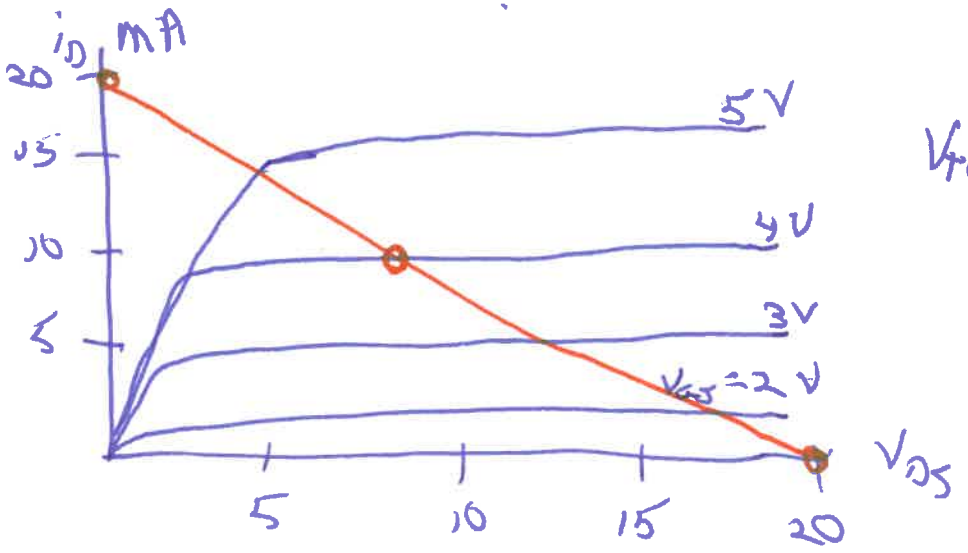
$$\text{slope} = K(V_{GS} - V_{TO})^2 \lambda$$

or $\frac{i_D}{V_A}$

Replace with a resistor $r_D = \frac{V_A}{I_D}$

Graphical Problems.





$V_{TO} = ?$

$K = ?$

$\frac{W}{L} = ?$

$V_{TO} \approx 1V$

$$K(V_{GS} - V_{TO})^2 = i_D$$

$$K(5V - 1V)^2 = 16\,mA \qquad K = \frac{1\,mA}{V^2}$$

$$\frac{W}{L} = \frac{2K}{50\mu A/V^2} = 40$$

Load Line

$V_{oc} = 20V$

$i_{sc} = 20mA$

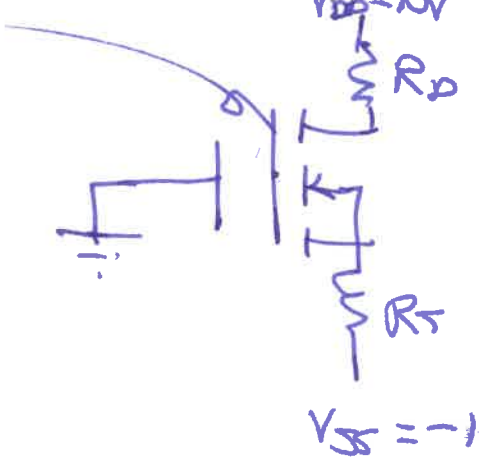
Q point $V_{GS} = 4V$ $\qquad (V_{GS} - V_{TO}) = 3V$

$I_D = 9\,mA$ $\qquad K \times (3V)^2$

Design Exmpl

$K = 25\,0\mu A/V^2$ $\qquad V_{TO} = 2V$

$\frac{W}{L} = 10$ $\qquad L = 4m$ $\qquad W = 100\mu m$



$I_D = 10\,mA$

$$I_D = K(V_{GS} - V_{TO})^2$$

$$I_D = K(+10V - I_D R_S - V_{TO})^2$$

$$10V - I_D R_S - V_{TO} = \sqrt{I_D/K}$$

$$R_S = \frac{10V - V_{TO} - \sqrt{I_D/K}}{i_D} = 167\Omega$$

$$V_S = -10V + i_D R_S = -10V + 1.67V$$

$$= -8.33V$$

$$(V_{GS} - V_{TO}) = 6.33\,V$$

$$i_D = K(6.33V)^2 = 10^{-2}A$$

$$V_{DS} > (V_{GS} - V_{TO}) = 6.33\,V \quad \text{for saturation}$$

$$V_D > -2V$$

Choose $V_D = 5V$

$$\therefore R_D = \frac{5V}{10^{-2}A} = 500\Omega$$