EE 42/100 Spring 2006 Problem Set 10

Solutions Prepared by Lynn Wang
ting Ø918@eecs.berkeley.edu.

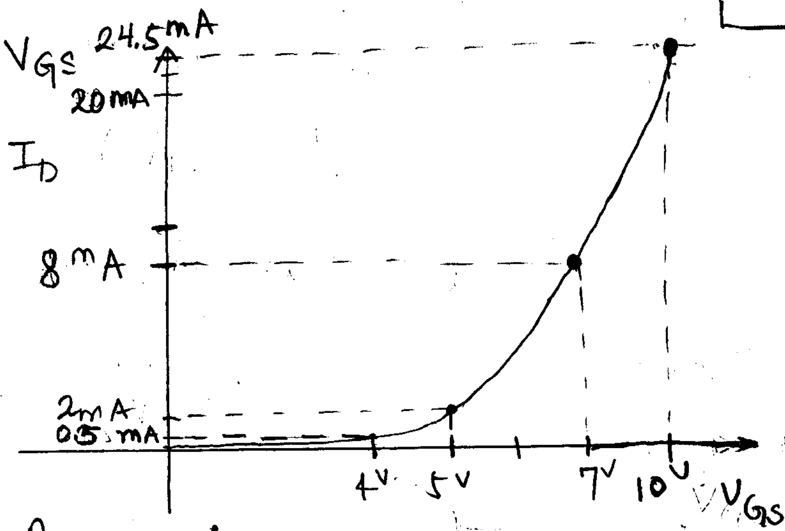
2. Hambley 3rd Ed, P12.4

$V_{to} = 3^V$
$K = 0.5\ ^{mA}/_{V^2}$
$V_{GS} = 5^V$

Triode Region $V_{GS} - V_{to} \geq V_{DS}$ $\Rightarrow$ $5 - 3 \geq V_{DS}$ $\boxed{2^V \geq V_{DS}}$

Saturation Region $V_{GS} - V_{to} \leq V_{DS}$ $\Rightarrow$ $5 - 3 < V_{DS}$ $\boxed{2^V \leq V_{DS}}$

I_D vs. V_{GS}



Assume Saturat^n reg^n:

$V_{gs}=5$ $I_d = \frac{K}{2}(V_{GS} - V_t)^2 = 0.5^m (5-3)^2 = 0.5^m(4) = 2^m A$

$V_{gs}=10$ $I_d = \frac{0.5^m}{2}(10-3)^2 = \frac{0.5}{2}(7)^2 = 49\left(\frac{1}{2}\right) = 24.5\ ^mA$

$V_{gs}=7$ $I_d = \frac{1}{4}(7-3)^2 = \frac{1}{2}(4)^2 = \frac{16}{2} = 8\ ^mA$

$V_{gs}=4$ $I_d = \frac{1}{2}(4-3)^2 = 0.5\ mA$

3. Hambley 3rd Ed. P.12.9

$I_D = 0.5\,mA$

$V_{GS} = V_{DS} = 5^V$

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

$V_{to} = 1^V$

$V_{GS} - V_{t_o} = 5^V - 1 = 4^V \leq V_{DS} = 5^V$

$\Rightarrow V_{DS} \geq V_{GS} - V_{to} \Rightarrow$ saturat^n reg^n.

$$I_d = K(V_{GS} - V_{to})^2 = \frac{1}{2} K_p \left(\frac{W}{L}\right)(V_{GS} - V_{to})^2$$

Solving for $\left(\frac{W}{L}\right)$ ratio:

$$\left(\frac{W}{L}\right) = \frac{2\,I_d}{K_p(V_{GS} - V_{to})^2} = \frac{2\,(0.5^m A)}{50\,\mu A/V^2\,(5-1)^2} = \frac{1^m}{50^\mu\,(4)^2} = \frac{1^m}{50^\mu(16)}$$

$$\boxed{\left(\frac{W}{L}\right) = 1.25}$$

For $L = 2\,\mu m$.

$$W = 2(1.25) = \boxed{2.5\,\mu m}$$

4. Hambley 3rd Ed, P.12.16

Why does distortion occur in FET amplifiers?

- curvature
- non-uniform spacing of characteristic curves

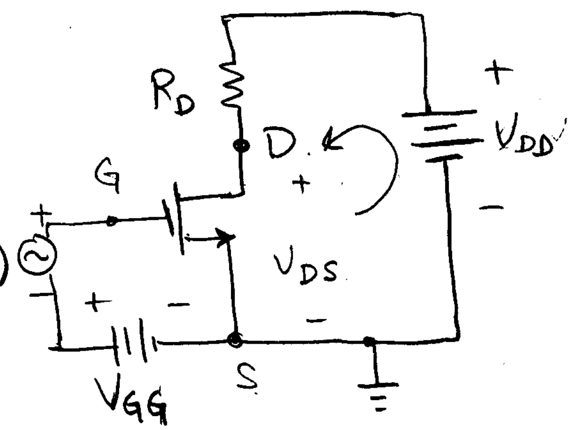
5. Hambley 3rd Ed, P.12.18

$i_D - v_{DS}$ axes – load lines

a. $R_D = 1^K\Omega$, $V_{DD} = 5^V$

b. $R_D = 1^K\Omega$, $V_{DD} = 10^V$

c. $R_D = 1^K\Omega$, $V_{DD} = 15^V$



Writing a KVL:

$$V_{DD} - i_D R_D - v_{DS}(t)$$

$$V_{DD} = i_D R_D + v_{DS}(t) \leftarrow \text{eq}^{n} \text{ for the load line}$$

a. $R_D = 1^K$, $V_{DD} = 5^V$

$$5 = i_D(1^K) + v_{DS}(t)$$

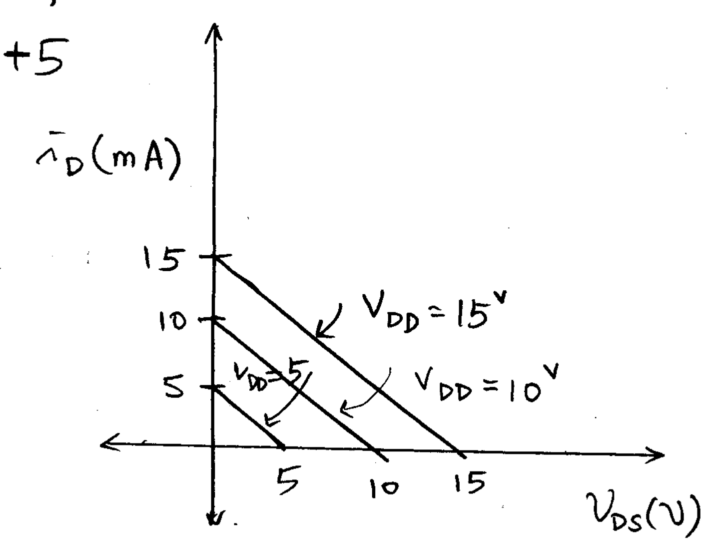
$$i_D(1^K) = -v_{DS}(t) + 5$$

$$i_D = \frac{5 - V_{DS}}{1^K}$$

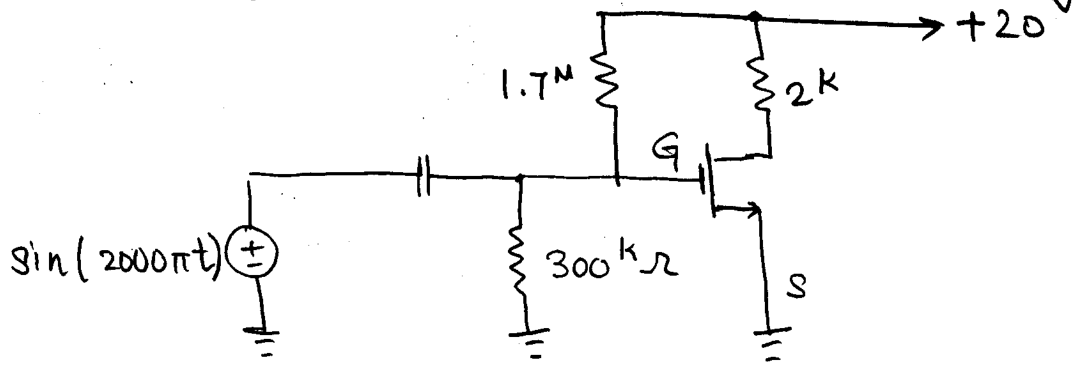
b. $$i_D = \frac{10 - V_{DS}}{1^K}$$

c. $$i_D = \frac{15 - V_{DS}}{1^K}$$

shifts to the right

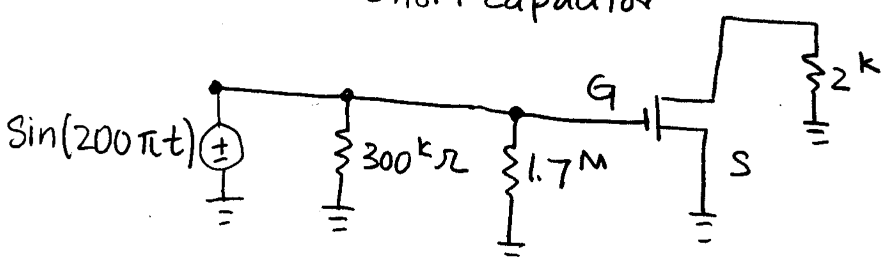


6. Hambley 3rd Ed, P. 12.20



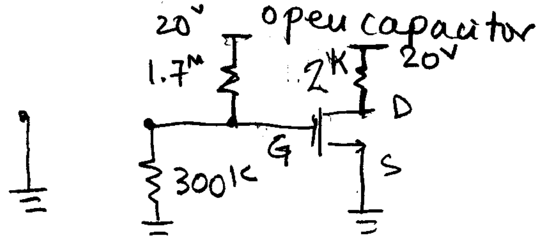
(a). Find $v_{GS}(t)$ (AC & DC).

AC signal (short DC voltage supplies)
short capacitor



$$V_{GS}(t)_{AC} = \sin(200\pi t)^{V}$$

DC signal (short all AC voltage supplies)
open capacitor



The $1.7^{M}\Omega$ and $300^{k}\Omega$ resistors act as voltage dividers

$$V_{GS_{DC}} = 20^{V}\left(\frac{300^{k}}{1.7^{M}+300^{k}}\right) = 3^{V}$$

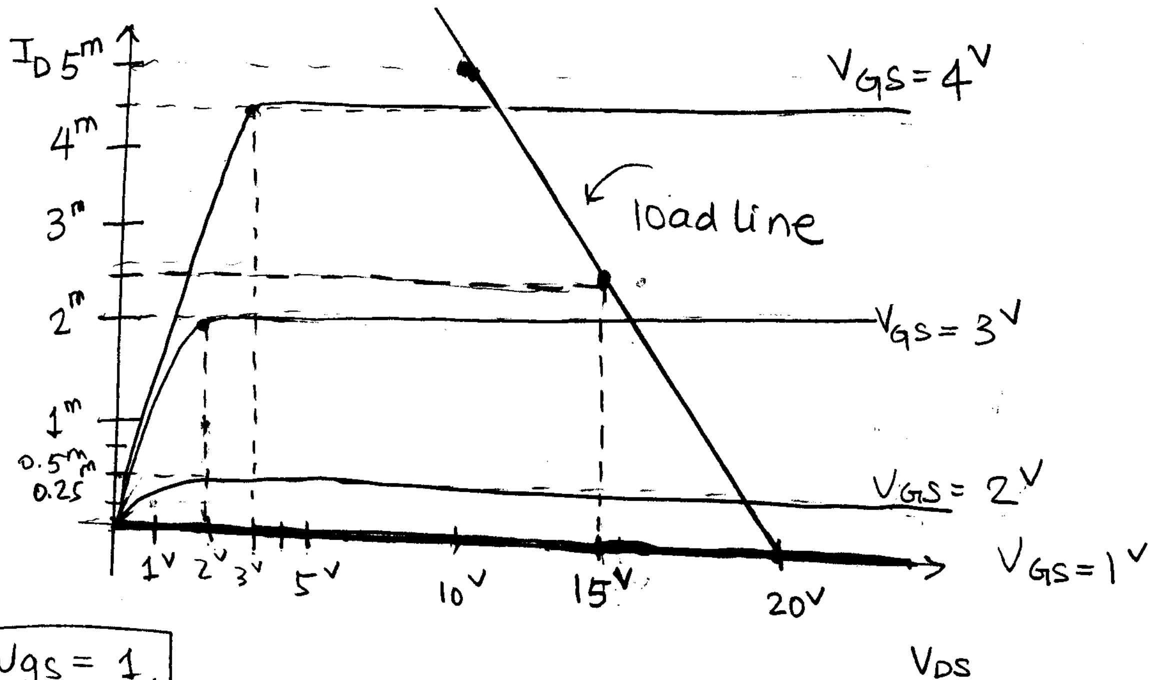
$$\boxed{V_{GS}(t) = V_{GS}(t)_{AC} + V_{GS_{DC}} = 3 + \sin(200\pi t)^{V}}$$

(b). FET

$V_{to} = 1^V$

$K = 0.5^{mA}/V^2$

$v_{gs} = 1, 2, 3, 4^V$



$v_{gs} = 1$

$v_{gs} - V_{to} = 1 - 1 = 0$ Device is off.

$V_{gs} = 2$

Triode $v_{gs} - v_{to} \geq v_{DS}$

$2 - 1 \geq v_{DS}$

$1 \geq v_{DS}$

$v_{DS} \leq 1$

saturat^n

$v_{DS} \geq 1$

$I_d = K(v_{gs} - V_{to})^2 = 0.5^m(2-1)^2 = 0.5^m A$

(c) Load line

$v_{DS} + i_D 2^K = 20^V$

$i_D = \dfrac{20^V - v_{DS}}{2^K}$

$$i_D = 10m - \frac{v_{DS}}{2^K}$$

- $V_{DS} = 20^V$ $i_D = 0$
- $V_{DS} = 15^V$ $i_D = 2.5^m A$
- $V_{DS} = 10^V$ $i_D = 5^m A$

$V_{gs} = 3$ $V_{gs} - V_{to} = 3 - 1 = 2^V$

sat. $V_{DS} \geq 2^V$ $id = 0.5^m(3-1)^2 = 4(0.5m) = 2^m A$

$v_{gs} = 4$ $V_{gs} - V_{to} = 4 - 1 = 3^V$

sat. $V_{DS} \geq 3^V$ $id = 0.5^m(4-1)^2 = \frac{9}{2} = 4.5^m A$

(d). V_{DSQ} ($V_{GS}(t) = 3^V$ b/c $v_{in}(t) = 0$) $\Rightarrow$ $i_d = 2^{m}A$

$$2^{m}A = 10m - \frac{V_{DS}}{2k} \Rightarrow V_{DS} = 16^V \Rightarrow \boxed{V_{DSQ} = 16^V}$$

$V_{DS\,max.}$ ($i_d = 0.5\,^{m}A$)

$$9.5\,mA = \frac{V_{DS}}{2k} \Rightarrow V_{DS} = 19^V \Rightarrow \boxed{V_{DS\,max} = 19^V}$$

$V_{DS\,min.}$ ($i_d = 4.5\,^{m}A$)

$$5.5 = \frac{V_{DS}}{2k} \Rightarrow V_{DS} = \boxed{V_{DS\,min} = 11^V}$$