# EECS 311: PS7 Solution

## P7.1

$I_D \propto (V_{SG} - |V_{tp}|)^2$ @ saturation region

$$\frac{50}{200} = \frac{(3 - |V_{tp}|)^2}{(5 - |V_{tp}|)^2}$$

$\Rightarrow |V_{tp}| = 1$ or $3.66$ (x)

Since this is PMOS device, $V_{tp} < 0$

$\Rightarrow \boxed{V_{tp} = -1\,V}$ #

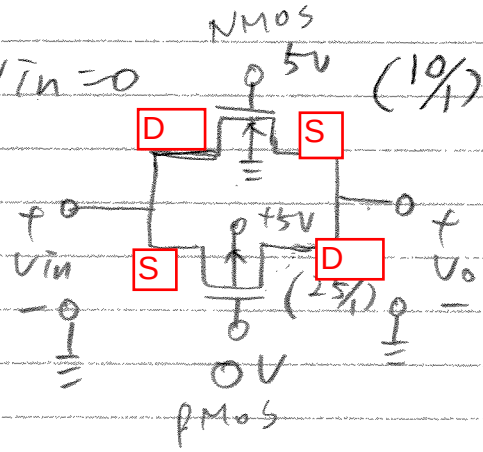
$$I_D = \frac{1}{2} k_p (V_{SG} - |V_{th}|)^2$$

$$200\mu = \frac{1}{2} k_p (5 - 1)^2$$

$$\Rightarrow \boxed{k_p = 25\,\mu A/V^2}$$ #

## P7.2

(a) $V_{in} = 0$




for $V_{in} = 0V$

NMOS: Vgs-Vth > 0

$\Rightarrow$ NMOS is on

PMOS: Vsg-Vth < 0

$\Rightarrow$ PMOS is off

$$r_{on} = \frac{1}{\mu_n C_{ox} (\frac{W}{L})(V_{GS} - V_{th})}$$

$$= \frac{1}{100\mu \times 10 \times (5 - 0.75)}$$

$$= \boxed{235\,\Omega}$$ #

(b) for $V_{in} = 5V$

NMOS: NMOS is off.

PMOS: PMOS is on. $V_{SG} = 5V$, $V_o = 5V$

$$r_{on} = \frac{1}{\mu_p C_{ox} (\frac{W}{L})(V_{SG} - |V_{th,p}|)} = \frac{1}{40 \times 10^{-6} \times 25 \times (5 - 0.75}$$

$$= \boxed{235\,\Omega}$$

P7.3 PMOS, $V_{BS} = 4V$, $V_{GS} = -1.5V$, $V_{DS} = -4$
$\left(\frac{W}{L}\right) = \frac{25}{1}$, region of operation ?

$$V_{TP} = -0.75 - 0.5(\sqrt{4 + 0.6} - \sqrt{0.6}) = -1.43$$

$$V_{SD} = 4 > V_{SG} - |V_{tp}| = 1.5 - 1.43 = 0.07$$

**Saturation region** #

$$I_D = \frac{1}{2} \times 40\mu \times \left(\frac{25}{1}\right)(1.5 - 1.43)^2$$

$$= \boxed{2.45\mu A} \#$$

P7.4 NPN transistor, $I_C = 1mA$, $I_B = 0.1mA$, $\beta_F = 100$
$\beta_R = 10$ $I_S = 10^{-15}A$, $V_T = 25mV$

$$\alpha_R = \frac{\beta_R}{\beta_R + 1} = \frac{10}{11}$$

$$V_{CEsat} = V_T \ln\left[\left(\frac{1}{\alpha_R}\right)\frac{1 + \frac{i_C}{(\beta_R + 1) i_B}}{1 - \frac{i_C}{\beta_F i_B}}\right]$$

$$= 25m \ln\left[\frac{11}{10} \times \frac{1 + \frac{1m}{11 \times 0.1m}}{1 - \frac{1m}{100 \times 0.1m}}\right]$$

$$= 25m \ln\left[\frac{11}{10} \times \frac{1 + 0.909}{1 - 0.1}\right]$$

$$= \boxed{21.2\ mV} \#$$

P7.5

$V_{BE} = 0.7$ (V)

$v_{be}(t) = 0.008 \sin(\omega_0 t)$ (V)

$V_{CE} = 5$ (V)

$v_{ce}(t) = -1.7 \sin(\omega_0 t + \pi)$ (V)

P7.6

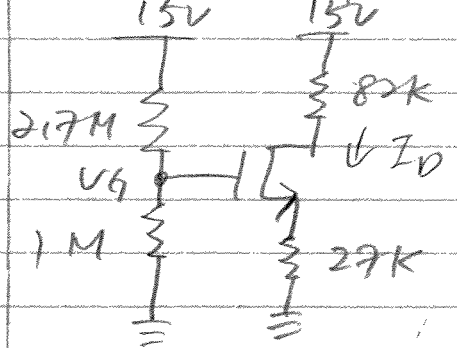
$v_{gs}(t) = 0.5 \sin(\omega_0 t)$ (V)

$V_{GS} = 3.5$ (V)

$V_{DS} = 9.8$ (V)

$v_{DS}(t) = +0.1 - 2 \sin(\omega_0 t + \pi)$ (V)

P7.7 $K_n = 250\,\mu A/V^2$, $V_{tn} = 1V$, $\lambda = 0$




$V_G = \frac{1}{1+2.7} \times 15 = 4.05\,V$

(a) Assume the transistor is in saturation region

$I_D = \frac{1}{2} K_n (V_{GS} - V_{th})^2$

$\Rightarrow I_D = \frac{1}{2} \times 250\mu (4.05 - I_D \times 27K - 1)^2$

$\boxed{I_D = 83\,\mu A}$ #

check if it's in saturation (V)

$I_D = \frac{1}{2} \times 250 \times 10^{-6} \times [(4.05 - 27\times10^3 I_D) - 1]^2$

$I_D = \boxed{83.433\mu A}$ or $152.94\mu A$ #(V)

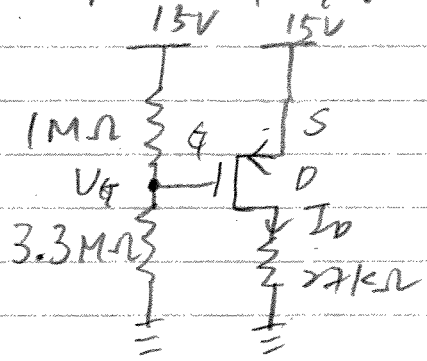
$\frac{83.433 - 83}{83} \times 100\% = \boxed{0.52\%}$ #

$I_D = \frac{1}{2} \times 250 \times 10^{-6} \times [(4.05 - 27\times10^3 I_D) - 0.95]^2$

$I_D = \boxed{84.389\,\mu A}$ or $156.29\mu A$ #(V)

$\frac{84.389 - 83}{83} \times 100\% = \boxed{1.67\%}$ #

P7.8 $K_p = 100\mu A/V^2$, $V_{tp} = -1V$, $\lambda = 0$




$V_G = \frac{3.3}{3.3+1} \times 15 = 11.51V$

(a) Assume the transistor is in saturation region.

$I_D = \frac{1}{2} K_p (V_{SG} - |V_{tp}|)^2$

$\Rightarrow I_D = \frac{1}{2} \times 100\mu \times (15 - 11.51 - 1)^2$

$= \boxed{310\mu A}$ #

$V_D = 27k \times 310\mu = 8.37V$

$V_{SD} = 15 - 8.37 = 6.63$, $V_{SG} - |V_{tp}| = (15 - 11.51) - 1 = 2.49$

$V_{SD} > V_{SG} - |V_{tp}| \Rightarrow$ Saturation.

(b) $I_D = \frac{1}{2} \times 105\mu \times (2.49)^2$

$= \boxed{325.5\mu A}$ #

$\frac{(325.5 - 310)}{310} \times 100\% = \boxed{5\%}$

(c) $I_D = \frac{1}{2} \times 100\mu \times [(15 - 11.51) - 0.95]^2$

$= \boxed{322.58\mu A}$

$\frac{(322.58 - 310)}{310} \times 100\% = \boxed{4.06\%}$

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