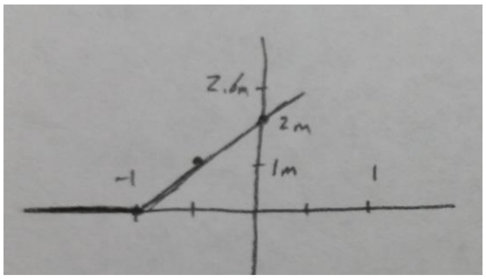
EE330 Fall 2017

Problem 1

a) $I_{DSSn} = I_{DSSn0} * \left(\frac{10}{2}\right) = 0.5\ mA,\ V_{pn}\ is\ a\ process\ parameter \rightarrow V_{pn} = -1\ V$

b) $g_m = \frac{\delta I_D}{\delta V_{GS}} = 2 * \frac{I_{DSS}}{V_P}(\frac{V_{GS}}{V_P} - 1)$



Problem 2:

a) $\frac{\mu_n C_{ox}}{2}\left(\frac{W}{L}\right)(V_{GS} - V_{out} - V_T)^2 = I_{DSS0} * \left(\frac{W}{L}\right)\left(1 - \frac{V_{GS}}{V_P}\right)^2$

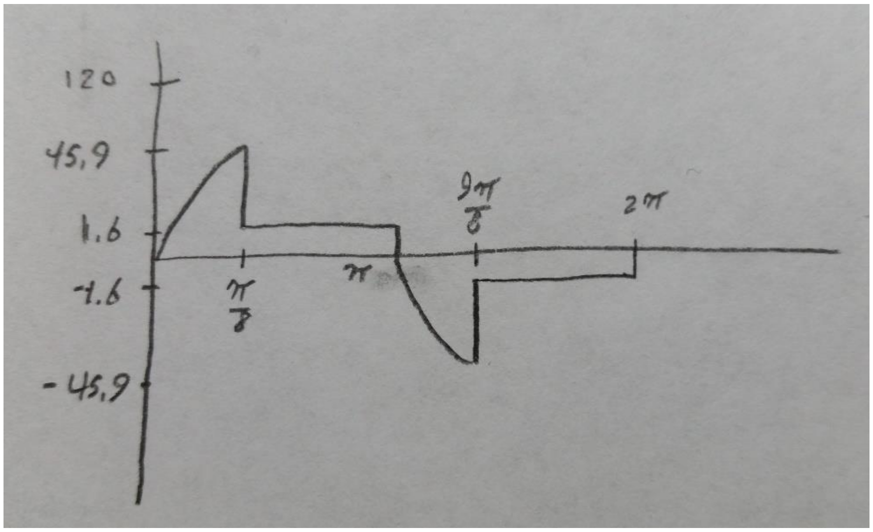
$\rightarrow \frac{100\mu}{2}\left(\frac{W_{mx}}{8\mu}\right)(5 - 3 - .75)^2 = 100\mu * \left(\frac{5}{2}\right)\left(1 - \frac{-2}{-3}\right)^2 \rightarrow W_{max} = 2.844\ \mu m$

b) $V_{out} = -g_{mJFET} * V_{GS} * R_{eq} \rightarrow A_V = -\frac{g_{mJFET}}{g_{mNMOS}}$

c)

$$A_V = \frac{\frac{2*I_{DSS0}*W}{V_P*L}(\frac{V_{GS}}{V_P}-1)}{\mu_n C_{ox}*\left(\frac{W}{L}\right)*(V_{GS}-V_T)} = 1.25$$

3a) $V_F = \begin{cases} V_{AC};\ 0 \le t \le \frac{\pi}{8},\ \pi \le t \le \frac{9\pi}{8} \\ 1.6;\ \frac{\pi}{8} \le t \le \pi \\ -1.6;\ \frac{9\pi}{8} \le t \le 2\pi \end{cases}$

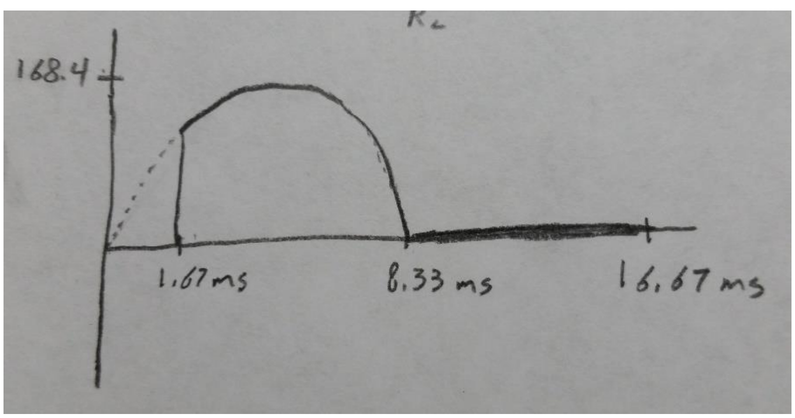


3b) Quadrants 2 and 3

4a) $V_G = V_{AC}\left(\frac{1000}{99000+1000}\right) = 170 * \sin(2\pi * 60 * t)\left(\frac{1}{100}\right)$

$V_G = 1 \text{ @ } 1.67\ ms\ and\ V_G = 0 \text{ @ } 8.33\ ms$

$V_L = V_{AC} - 1.6\ or\ 0$



b) $P_{avg} = \frac{V_{RMS}^2}{R}$

$$V_{RMS} = V_P\sqrt{\frac{1}{16.67}\int_{0.00167}^{0.00833}\sin^2(120\pi * t)\,dt} = 2.6057 \;\rightarrow\; P_{avg} = 0.339\,W$$

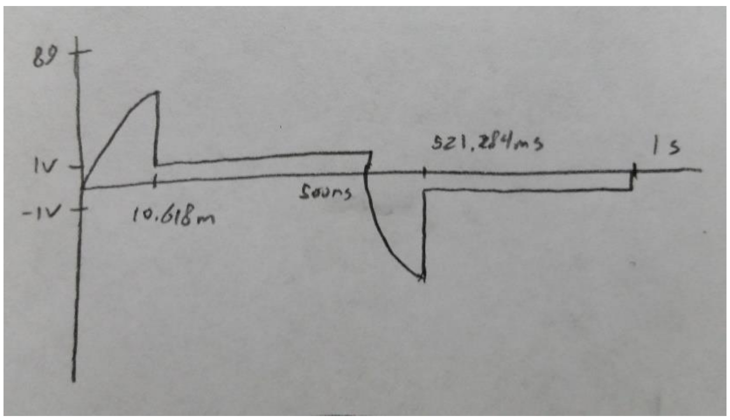
5a)

$V_{AC}\ positive \rightarrow diode\ is\ off$

$$\rightarrow\ V_G = -\frac{V_{AC}}{3000} * 1000 = -2\ @\ 10.618\ ms$$

$V_{AC}\ negative \rightarrow diode\ is\ on$

$$\rightarrow\ V_G = -\frac{-\left(V_{AC} - \frac{V_{AC}}{2}\right)}{3000} * 1000 = \frac{-V_{AC}}{6} = 2\ @\ 521.284\ ms$$



b) $P_{avg} = I_{RMS}V_{RMS}, \rightarrow I_{RMS}\sqrt{\frac{1}{T}\int_{0.010618}^{0.5} \sin^2(2\pi * t)\, dt + \int_{0.521284}^{1} \sin^2(2\pi * t)\, dt}$

$V_{RMS} = 1 * \big(1 - (0.010618 + 0.021284)\big) = 0.968 \rightarrow\ P_{avg} = 3.046\ W$

c) Quadrants 2 and 4

Problem 6

$$I_D = \mu_n C_{ox}\left(\frac{W}{L}\right)\left(V_{GS} - V_T - \frac{V_{DS}}{2}\right)V_{DS}, I_G \approx 0$$
$$I_G = y_{11}V_{GS} + y_{12}V_{DS}$$
$$I_D = y_{22}V_{DS} + y_{21}V_{GS}$$
$$y_{11} = \frac{\delta I_G}{\delta V_{DS}} = 0$$
$$y_{12} = \frac{\delta I_G}{\delta V_{GS}} = 0$$

$$y_{22} = \frac{\delta I_D}{\delta V_{DS}} = \mu_n C_{ox}\left(\frac{W}{L}\right)(V_{GS} - V_T - V_{DS}) = g_o$$

$$y_{21} = \frac{\delta I_D}{\delta V_{gS}} = \mu_n C_{ox}\left(\frac{W}{L}\right)V_{DS} = g_m$$

Problem 7

A) $V_{GS} - V_T = 2 - .75 = 1.25\ V = V_{DS_{min}}$

$V_{DS_{min}} = 5V - (6k)(I_{Dmax}) + 2\text{V} \rightarrow I_{Dmax} = 0.958\ mA$

$I_{Dmax} = \frac{\mu_n C_{ox}}{2}\left(\frac{W}{L}\right)_{max}\left(V_{gs} - V_T\right)^2 = 1\ A$

$\left(\frac{W}{L}\right)_{max} = 19.17$

if $L = 1\mu m, W_{max} = 19.17\mu m$

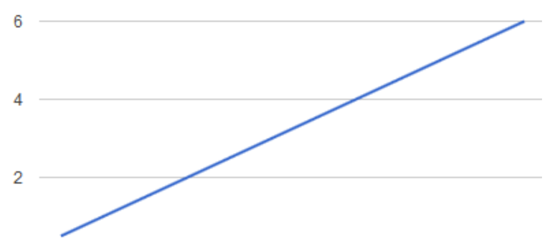
B) gain = $g_m R = g_m(6k)$

$g_m = \frac{I_{DQ}}{V_{GSQ}} = \frac{\mu C_{ox}\left(\frac{W}{L}\right)(V_{GS} - V_T)}{2}, \frac{W}{L} = W$

$\frac{100 * 10^{-6} * W * 1.25}{2} = g_m$

$g_m = W * 62.5 * 10^{-6}$

$A_V = -W * 0.375$



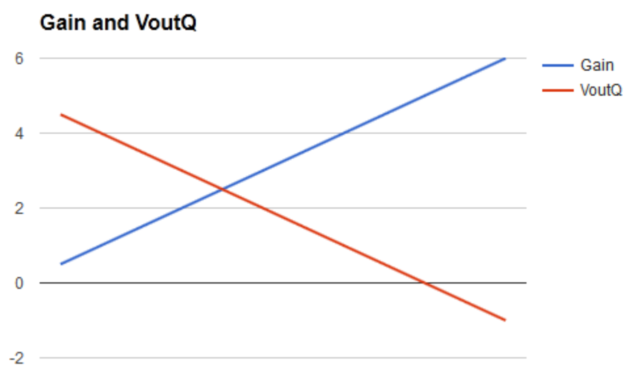
C)

$V_{outQ} = 5V - (6k)\left(I_{DQ}\right)$

$I_{DQ} = 78.125 * W * 10^{-6}$

$V_{outQ} = 5V - (6k)(78.125 * W * 10^{-6})W$

$V_{outQ} = 5V - W * 0.468.75\ V$



Problem 8

$$I_{DQ} = \mu C_{ox}\left(\frac{W}{2L}\right)\left(V_{gs} - V_T\right)^2 = 0.002344 \rightarrow 5 - (6k) * I_{DQ} = -4.375 \text{ not saturation}$$

$$I_{DQ} = \mu C_{ox}\left(\frac{W}{L}\right)\left(V_{GS} - V_T - \frac{V_{DS}}{2}\right)V_{DS} = \frac{5 - V_{DS} + 2}{6000}$$

$$V_{DS} = 0.5516\text{ V} \rightarrow I_{DQ} = 1.075\text{ mA}$$

$$A_V = -\frac{2I_{DQ}R_D}{V_G} = -\frac{2(0.001075)(6k)}{2}$$

$$A_V = -6.448$$

If the MOSFET were in saturation and W = 20, gain would have been -7.5, so it's smaller now.

Problem 9

a)

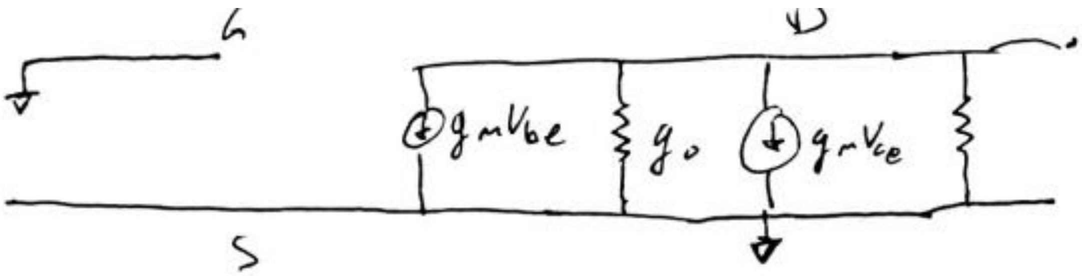
$I_{D1} = I_{D2}$, Assume both are in saturation $\rightarrow I_D = \mu C_{ox}\left(\frac{W}{2L}\right)(V_{GS} - V_T)^2$

$V_{GS1} = 1.25V \quad | \quad V_{GS2} = 5V - V_{out}$

$$\frac{\mu_n}{\mu_p} = \frac{\frac{W_1}{L_1}}{\frac{W_2}{L_2}} * \left(\frac{(V_{GS1} - 1)}{5 - V_{out} - 1}\right)^2 = 1$$

$V_{out} = 2.5V$

b)



$$R_c \approx \frac{1}{g_m + g_0} \approx \frac{1}{g_{m2}}$$

$$A_V = g_{m1} R_c = g_{m1} * \frac{1}{g_{m2}} = \frac{g_{m1}}{g_{m2}}$$

$$A_V = \frac{\mu_n}{\mu_p} * \frac{\frac{W_1}{L_1}}{\frac{W_2}{L_2}} * \frac{V_{GS1} - V_{TN}}{V_{GS2} - V_{TP}}$$

$$A_V = 3 * \frac{\frac{16}{3}}{\frac{4}{9}} * \left(\frac{0.25}{0.5}\right)$$

$A_V = 6$

c)

$$R_m = \frac{1}{g_{m1}} = \frac{1}{\mu_n C_{os} \left(\frac{W_1}{L_1}\right) (V_{GS1} - V_{TN})}$$

$R_m = 7.5k\Omega$

Problem 10

a)

$$I_{D1} = \mu_n C_{ox} \left(\frac{W_1}{2L_1}\right) (V_{GS1} - V_{TN})^2 \mid I_{D2} = \mu_p C_{ox} \left(\frac{W_2}{2L_2}\right) (V_{GS1} - V_{TP})^2$$

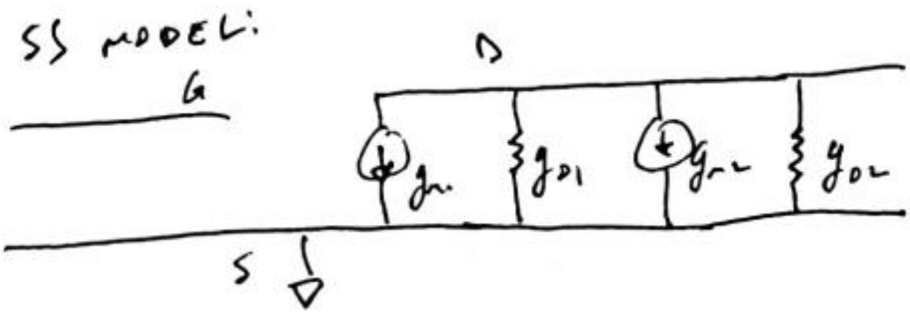
$V_{GS1} = 1.25V$

$V_{GS2} = 5V - V_{out} \quad | \quad I_{D1} = I_{D2}$

$$\frac{\mu_n}{\mu_p} * \frac{\frac{W_1}{L_1}}{\frac{W_2}{L_2}} * \left(\frac{V_{GS1} - V_{TN}}{V_{GS2} - V_{TP}}\right)^2 = 1$$

$V_{outQ} = 2.5V$

b)



$$A_V = -\frac{g_{m1}}{-g_{m2}}$$

$A_V = -6$

c) $R_{in} = \infty$

Problem 11

Code:

```
module PriorityEncoder8to3(iD, oQ);
  input [7:0] iD;
  output [2:0] oQ;
  reg [2:0] Q;

  assign oQ = Q;

  always @(iD) begin

    if (iD[7] == 1) begin
      Q <= 7;
    end else if(iD[6] == 1) begin
      Q <= 6;
    end else if(iD[5] == 1) begin
      Q <= 5;
    end else if(iD[4] == 1) begin
      Q <= 4;
    end else if(iD[3] == 1) begin
      Q <= 3;
    end else if(iD[2] == 1) begin
      Q <= 2;
    end else if(iD[1] == 1) begin
      Q <= 1;
    end else begin
      Q <= 0;
    end

  end

endmodule
```

Testbench:

```
`timescale 1ns/1ps
module PriEnc8to3_tb();
  reg [7:0] D;
  wire [2:0] Q;

  PriorityEncoder8to3 DUT(.iD(D), .oQ(Q));

  initial begin
    D <= 8'b00000001;
    #20;
    D <= 8'b00000011;
    #20;
    D <= 8'b00000111;
    #20;
    D <= 8'b00001111;
    #20;
    D <= 8'b00001011;
    #20;
    D <= 8'b00011011;
    #20;
    D <= 8'b00111011;
    #20;
    D <= 8'b01111011;
    #20;
    D <= 8'b11111011;
    #20;
    D <= 8'b10010000;
    #20;

  end

endmodule
```

Output: