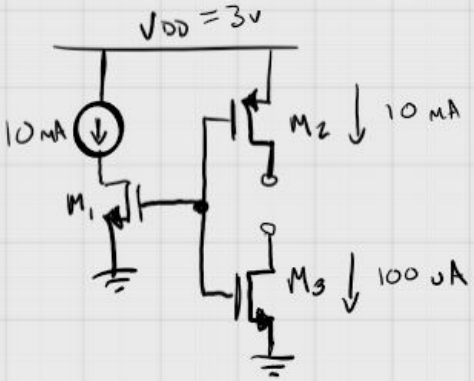
EE 330 HW 12

1) $I_O = 250 \cdot \dfrac{(W_2/L_2)\cdot(W_4/L_4)}{(W_1/L_1)\cdot(W_3/L_3)} \Rightarrow (250\,\mu A)\dfrac{(2)(5)}{(5)(20)} = \boxed{25\,\mu A}$

2)



a) Setting $\frac{W_1}{L_1}$ of $M_1 = 1 \Rightarrow \frac{1\mu}{1\mu}$

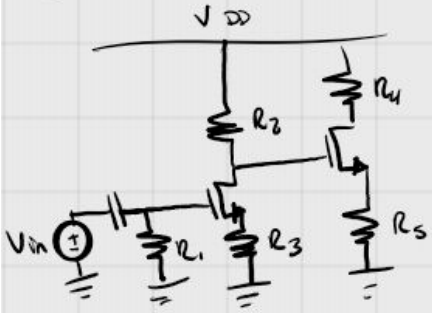
M_2 must be $= 1 \Rightarrow \frac{1\mu}{1\mu} = \frac{W_2}{W_1}$

M_3 must be $= .01 \Rightarrow \frac{1\mu}{100\mu} = \frac{W_3}{L_3}$

b) $I_{M_2} = \dfrac{(\mu_p C_{ox})}{2}\cdot\dfrac{W_2}{L_2}(V_{GS}-V_T)^2 \Rightarrow (V_{GS}-V_T)^2 = \dfrac{10\,mA\cdot 2\cdot L_2}{(\mu_p C_{ox})(W_2)} \Rightarrow$

$(V_{GS}-V_T)^2 = \dfrac{10\,mA\cdot 2\cdot 1}{(70\mu\cdot 10^{-6})(1)} = \boxed{16.9\,V}$

3) Use 2 stage CE:



$A_{Tot} = A_1 \cdot A_2 \qquad A_2 = -\dfrac{R_2}{R_3}$

$A_1 = -\dfrac{R_2 \,||\, R_{in_2}}{R_3} \qquad R_{in_2} = \infty$

$A_{Tot} = \dfrac{R_2 \cdot R_4}{R_3 \cdot R_5} = 5$

Choose: $R_4 = 5k$, $R_2 = R_3 = R_5 = 1k$

$R_{in} \approx R_1$, set $\boxed{R_1 = 150k}$

4) $M = \frac{W_2 \cdot L_1}{W_1 \cdot L_2} \Rightarrow \frac{10}{2} \cdot \frac{4}{4}$, with encroachment on W,

$M = \frac{10 - 2(.1)}{2 - 2(.1)} \cdot \frac{4}{4} = \boxed{5.4}$

5) V_{o_1}: Current through R_1 dictates current through Q_1, dictates current through Q_2, dictates current through Q_3 $\Rightarrow$

$V_{o_1} = \bar{I}_3 \cdot R_2 \Rightarrow \bar{I}_3 = \left(\frac{A_3}{A_2} \cdot \beta\right) \cdot \bar{I}_2 \Rightarrow V_o = \left(\frac{A_3}{A_2} \cdot \beta\right) \cdot \bar{I}_2 \cdot R_2$

$\bar{I}_2 = \frac{10 - .6}{R_1}$ $\boxed{V_{o_1} = \left(\frac{A_3}{A_2} \cdot \beta\right)\left(\frac{9.4}{R_1}\right) \cdot R_2}$

V_{o_2}: $\bar{I}_{R_1} \rightarrow \bar{I}_{Q_4} \rightarrow \bar{I}_{M_5} \rightarrow \bar{I}_{M_6}$

$V_{o_2} = \bar{I}_{M_6} \cdot R_3 \Rightarrow \bar{I}_{M_6} = \left(\frac{W_6 \cdot L_5}{W_5 \cdot L_6}\right)\left(\frac{A_4}{A_1} \cdot \beta\right) \cdot \bar{I}_1 \cdot R_3$

$\bar{I}_1 = \frac{10 - .6}{R_1} \Rightarrow \boxed{V_{o_2} = \left(\frac{W_6 \cdot L_5}{W_5 \cdot L_6}\right)\left(\frac{A_4}{A_1} \cdot \beta\right)\left(\frac{9.4}{R_1}\right) \cdot R_3}$

b) $V_{o_1} = \left(\frac{25\text{u}^2}{100\text{u}^2} \cdot 100\right)\left(\frac{9.4}{60\text{k}}\right) \cdot R_2$ For $V_{o_1} = 6\text{V}$, $\boxed{R_2 = 1532\,\Omega}$

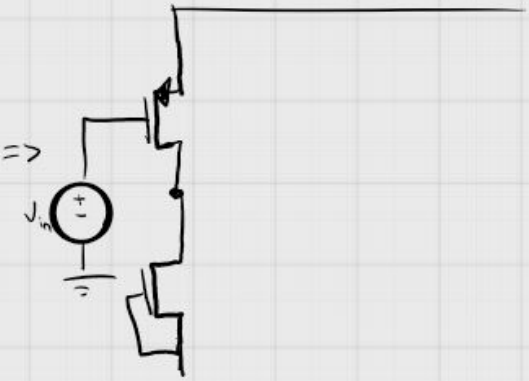
$V_{o_2} = \left(\frac{16\text{u} \cdot 1\text{u}}{10\text{u} \cdot 4\text{u}}\right)\left(\frac{300\text{u}^2}{100\text{u}^2} \cdot 100\right)\left(\frac{9.4}{60\text{k}}\right) \cdot R_3$ For $V_{o_2} = 3\text{V}$, $\boxed{R_3 = 160\,\Omega}$

6) $A_1 = -\frac{g_{m1}}{g_{m2}}$ $\quad A_2 = -\frac{g_{m4}}{g_{m3}}$ $\quad A_3 = -\frac{g_{m5}}{g_{m6}}$

$$\boxed{A_{Tot} = -\left(\frac{g_{m1}}{g_{m2}}\right)\left(\frac{g_{m4}}{g_{m3}}\right)\left(\frac{g_{m5}}{g_{m6}}\right)}$$

b) $I = (\mu C_{ox})\left(\frac{W}{2 \cdot L}\right)(V_{GS} - V_T)^2 \Rightarrow$

$$V_{GS} = V_T + \sqrt{\frac{I \cdot 2 \cdot L}{(\mu C_{ox})(W)}}$$

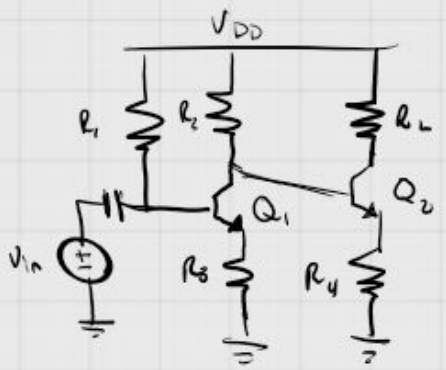


Jo. Why the fuck. Is there so much work for this class? It's so counterproductive.

7) $A_V = \frac{V_o}{V_i} \Rightarrow V_o = -\frac{R_2 \cdot V_A}{R_3}$ $\quad V_{in} = V_A \Big/ (g_{m2} \cdot R_1)\left(\frac{g_{m1}}{g_{m1} + g_{m2}}\right)$

$$\frac{V_o}{V_{in}} = -\frac{R_2 \cdot \cancel{V_A}}{R_3} \cdot \frac{(g_{m2} \cdot R_1)\left(\frac{g_{m1}}{g_{m1} + g_{m2}}\right)}{\cancel{V_A}} \Rightarrow \boxed{-\frac{R_1 \cdot R_2 \cdot g_{m1} \cdot g_{m2}}{R_3 (g_{m1} + g_{m2})}}$$

10) Use two CGs in series



$A_{Tot} = A_{stage_1} \cdot A_{stage_2} = 60$

$A_{stage_1} = -\frac{R_L}{R_4}$

$A_{stage_2} = -\frac{(R_2 \parallel R_{in_2})}{R_3}$ $\qquad R_{in_2} = \left(\frac{V_T}{I_{C_2}} + R_4\right)\cdot\beta \Rightarrow \left(\frac{.026}{I_{C_2}} + R_4\right)\cdot 100$

If we make $A_{stage_1} = -6$, A_{stage_2} must $= -10$

$R_L = 1k$

$A_{stage_1} = -\frac{R_L}{R_4} \Rightarrow -\frac{1000}{R_4} \Rightarrow \boxed{R_4 = 166.\bar{6}\,\Omega}$

$I_{C_2} = \beta \cdot I_{B_2} \Rightarrow I_{B_2} = \frac{V_{DD} - .6 - V_{R_4}}{R_2} = \frac{V_{R_4}}{R_4} \Rightarrow$ Choose $V_{DD} = 3V$, $R_2 = R_4$ $\Rightarrow$

$\frac{3 - .6 - V_{R_4}}{166.\bar{6}} = \frac{V_{R_4}}{166.\bar{6}}$ $\quad 2V_{R_4} = 2.4$ $\quad V_{R_4} = 1.2V$ $\quad I_B = .0072$ $\quad I_C = .72$

$A_{stage_2} = -\frac{(166.\bar{6} \parallel \left(\frac{.026}{.72} + 166.\bar{6}\right)\cdot 100)}{R_3} = -10 \Rightarrow \frac{(166.\bar{6} \parallel 16676)}{R_3} = 10$

$10 = \frac{165.08}{R_3}$ $\quad \boxed{R_3 = 16.5\,\Omega}$ $\qquad \boxed{R_1 = 5M\Omega}$ should work

This question took over an hour.

I have another project and a half to do by Friday

I am not verifying this in spice.

11) $A_V = -\left(1k \parallel \frac{1}{g_{o1}} \parallel \frac{1}{g_{o2}}\right)(g_{M1} + g_{M2})$ $\quad V_T = .026$

$g_{M1} = \frac{I_C}{V_T}$ $\quad g_{M2} = \frac{2 \cdot I_C}{V_{GS} - V_T}$ $\quad I_C = J_S \cdot A_E \cdot e^{\frac{V_{BE}}{V_T}} = .0105\ A$

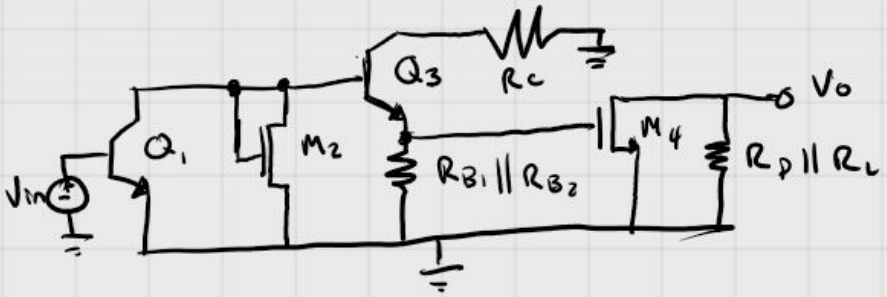
$g_{M1} = .404$ $\quad g_{M2} = .0046$

$g_{o1} = \frac{I_C}{V_{AF}} = \frac{.0105}{100} = 105 \cdot 10^{-6}$ $\quad g_{o2} = \lambda \cdot I_C = .01 \cdot .0105 = 105 \cdot 10^{-6}$

$A_V = -\left(1k \parallel \left(\frac{1}{105 \cdot 10^{-6}}\right) \parallel \left(\frac{1}{105 \cdot 10^{-6}}\right)\right)(.404 + .0046) \Rightarrow \boxed{-337.69}$

b) $V_o = -337.69 \cdot .01 \sin(1000t) = \boxed{3.38 \sin(1000t)}$

12)



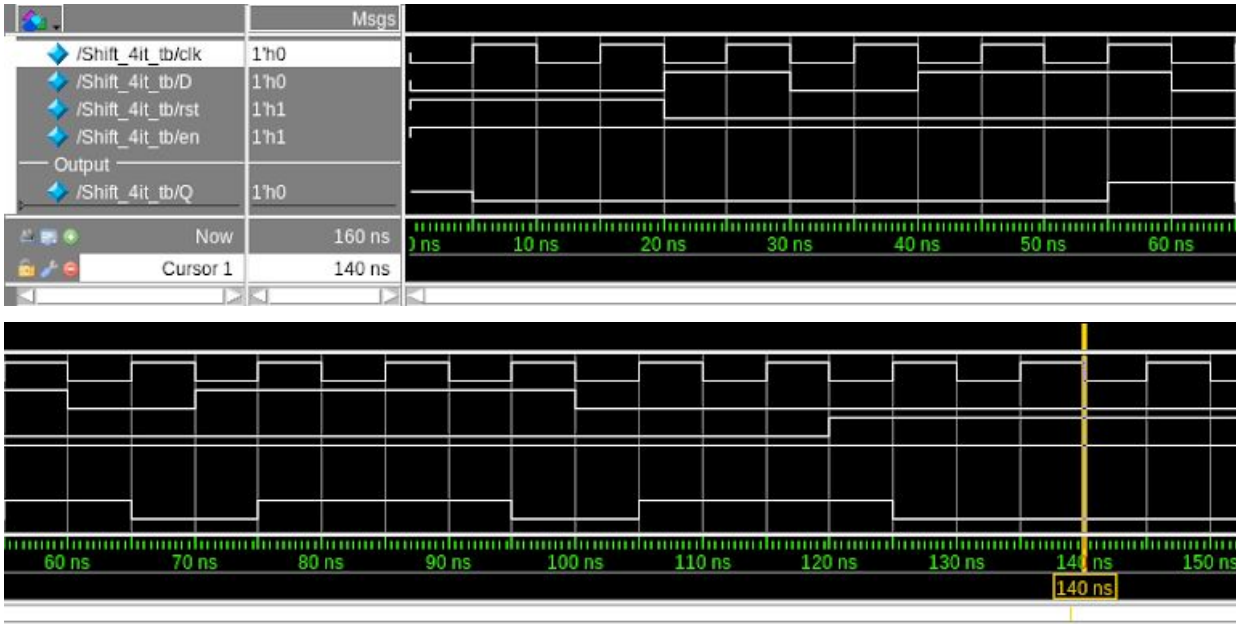
b) N 3 stages

$A_V = \left(-g_{M1}\left(R_{in3} \parallel \frac{1}{g_{M2}}\right)\right) \cdot \left(g_{M3}\left(\frac{R_C}{R_{B1} \parallel R_{B2}}\right)\right) \cdot \left(-g_{M4}\left(R_D \parallel R_L\right)\right)$

What was the point of this exercise? I feel very strongly that my time could have been better spent elsewhere.

```
//-----------------------------------
// D flip flop with enable designed to
// only change value on clock posedge
//
// Sean Gordon
// SGordon4
//-----------------------------------
module DFF_Sync (
      D,
      clk,
      rst,
      en,
      Q
);
      input D, clk, rst, en;
      output Q;
      reg Q;

      always @ ((posedge clk) or en)
      if(en) begin
          if(rst) begin
              Q <= 0;
          end
          else begin
            Q <= D;
          end
      end
endmodule



//-----------------------------------
// 4-Bit shift register built from
// synchronous D-Flip-Flops
//
// Sean Gordon
// SGordon4
//-----------------------------------
```

```
module Shift_4Bit(
      D,
      clk,
      rst,
      en,
      Q
);
      input D, clk, rst, en;
      output Q;
      wire s_D1_2, s_D2_3, s_D3_4;

      DFF_Sync DFF1(
          .D      (D),
          .clk    (clk),
          .rst    (rst),
          .en     (en),
          .Q      (s_D1_2)
      );
      DFF_Sync DFF2(
          .D      (s_D1_2),
          .clk    (clk),
          .rst    (rst),
          .en     (en),
          .Q      (s_D1_3)
      );
      DFF_Sync DFF3(
          .D      (s_D1_3),
          .clk    (clk),
          .rst    (rst),
          .en     (en),
          .Q      (s_D1_4)
      );
      DFF_Sync DFF4(
          .D      (s_D1_4),
          .clk    (clk),
          .rst    (rst),
          .en     (en),
          .Q      (Q)
      );

endmodule
```




```
`timescale 1ns/10ps
module Shift_4it_tb;
      reg D;
      reg clk, rst, en;
      wire Q;
      localparam period = 5;

      Shift_4Bit shift(
          .D      (D),
          .clk    (clk),
          .rst    (rst),
          .en     (en),
          .Q      (Q)
      );
      //Do basic setup
      initial begin
          clk = 1'b0;
          en  = 1'b1;
          rst = 1'b1;
          repeat(4) #period clk = ~clk;

          rst = 1'b0;
          forever #period clk = ~clk; // generate a clock
      end
      initial begin
```

```
        //Wait for setup to stop before beginning
        D = 0;
        @(negedge rst);

        D = 1;
        repeat(1) @(negedge clk);
        D = 0;
        repeat(1) @(negedge clk);
        D = 1;
        repeat(1) @(negedge clk);
        D = 1;
        repeat(1) @(negedge clk);

        D = 0;
        repeat(1) @(negedge clk);
        D = 1;
        repeat(1) @(negedge clk);
        D = 1;
        repeat(1) @(negedge clk);
        D = 1;
        repeat(1) @(negedge clk);

        //Let the shift register propogate out
        D = 0;
        repeat(1) @(negedge clk);
        D = 0;
        repeat(1) @(negedge clk);
        D = 0;
        rst = 1;            //Show reset works
        repeat(1) @(negedge clk);
        D = 0;
        repeat(1) @(negedge clk);


        //$finish;
    end

endmodule
```