EE330 Homework 7 Spring2018 TA: George Alphonse

Problem 1

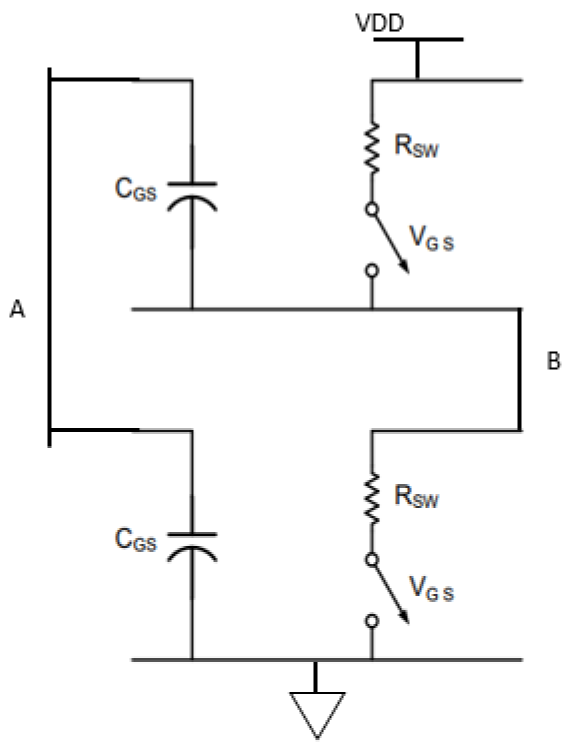
For the circuit on the left, the anode voltage can't exceed the cathode voltage of 15 V, so diode is off.

$$I_1 = \frac{7}{2k + 2k} = 1.75\ mA$$

For the circuit on the right, the resistors act as a voltage divider so V_D = 15*(4/6) = 10 V, so diode is on.

$$I_1 = \frac{9.6}{4k} = 2.40\ mA$$

Problem 2



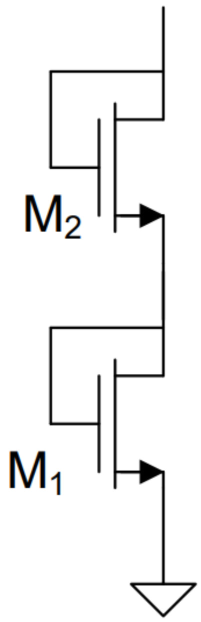
$$R_{sqn} = \frac{1}{\frac{\mu C_{ox} W}{L}(V_{GS} - V_T)} = \frac{1}{\frac{350\mu A}{V^2} * \frac{5\mu}{1\mu} * (3.5 - 0.5)} = 190\Omega$$

$$R_{sqp} = \frac{1}{\frac{70\mu A}{V^2} * \frac{20\mu}{2\mu} * (3.5 - 0.5)} = 476\Omega$$

$$C_{GSN} = C_{OX} WL = (2.5 fFu^{-2})(5\mu * 1\mu) = 12.5\ fF$$

$$C_{GSP} = (2.5 fF\mu^{-2})(20\mu * 2\mu) = 100 fF$$

Problem 3



Assume both transistors are in saturation

$$u_n C_{OX} * \frac{W_1}{2L_1} * (V_{out} - V_{ss} - V_T)^2 = u_n C_{OX} * \frac{W_2}{2L_2} * (V_{DD} - V_{out} - V_T)^2$$

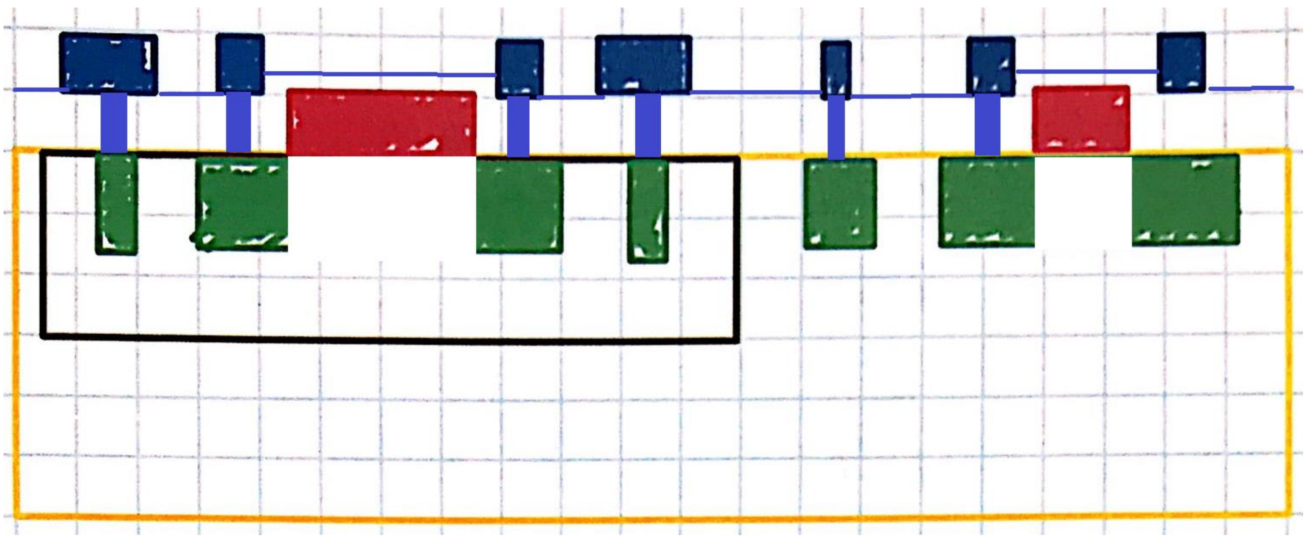
$$u_n C_{OX} * \frac{W_1}{2L_1} * (1V - 0V - 0.5V)^2 = u_n C_{OX} * \frac{W_2}{2L_2} * (2.5V - 1V - 0.5V)^2$$

$$\frac{W_1}{L_1} * (1V - 0.5V)^2 = \frac{W_2}{L_2} * (2.5V - 1V - 0.5V)^2$$

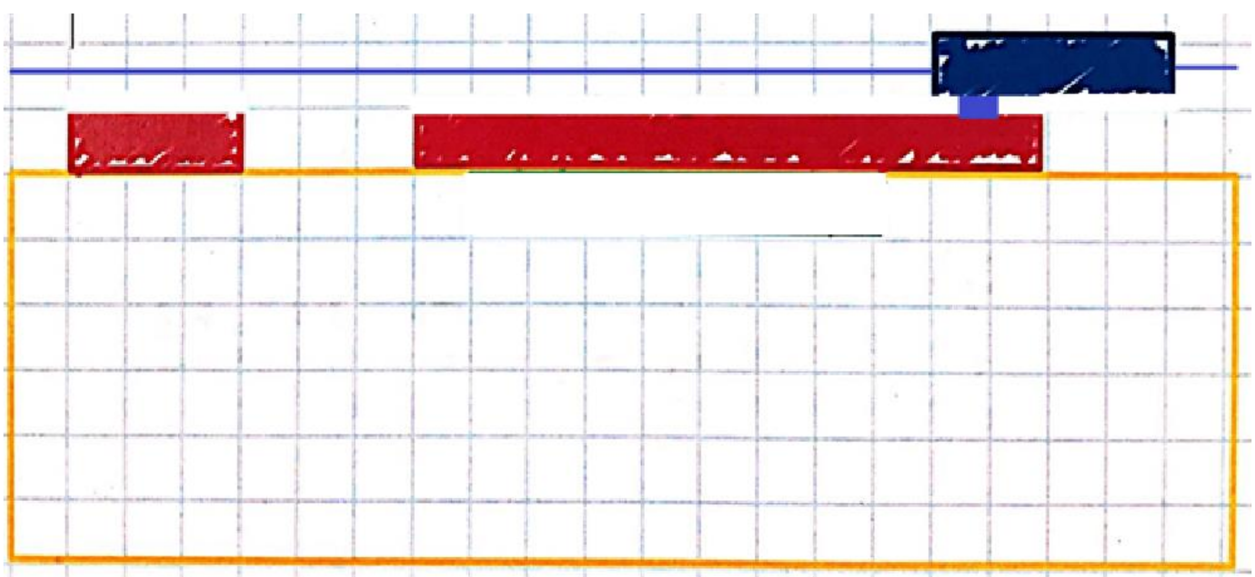
$$\frac{\frac{W_2}{L_2}}{\frac{W_1}{L_1}} = \frac{(1V - 0.5V)^2}{(2.5V - 1V - 0.5V)^2} = 0.25$$

$$If\,\frac{W_1}{L_1} = \frac{9.6\mu}{0.6\mu} = 16\; then\,\frac{W_2}{L_2} = \frac{2.4\mu}{0.6\mu} = 4$$

Problem 4



Problem 5



Problem 6

Same as problem 5

Problem 7

A.)

$$\alpha = \frac{I_C}{I_E} = \frac{1.00mA}{1.0250mA} = 0.9756$$

$$\beta = \frac{\alpha}{1-\alpha} = \frac{0.9756}{1-0.9756} = 40$$

B.)

$$\alpha = \frac{1.00mA * 1.005}{1.0250 * (1-.005)} = 0.985$$

$$\beta = \frac{0.985}{1-0.985} = 67.56$$

$$Error = \frac{67.56-40}{40} = 0.689 = 68.9\%$$

Problem 8

$$I_B = \frac{I_C}{\beta} = \frac{1.00mA}{40} = 25\mu A$$

$$\beta = \frac{I_C}{I_B} = \frac{1.00mA * 1.005}{25\mu A * 0.995} = 40.402$$

$$Error = \frac{40.402-40}{40} = 0.01005 = 1.005\%$$

Problem 9

A.)

$$I_C = \frac{8V - 5V}{3k\Omega} = 1.00mA$$

$$V_t = \left(8.617 * 10^{-5}\frac{eV}{K}\right)(300K) = 25.85mV$$

$$I_C = J_s A_E e^{\frac{V_{BE}}{V_t}} = 10^{-14} * 100 * e^{\frac{V_{BE}}{25.85mV}} \rightarrow V_{BE} = 0.536V$$

B.)

$$I_C = J_s A_E e^{\frac{V_{BE}}{V_t}} = 10^{-14} * 100 * e^{\frac{0.536V - 10uV}{25.85mV}} = 999.6uA$$

$$V_C = 8V - 3k\Omega * 999.6uA = 5.00118\,V$$

$$Change = \frac{5V}{5.00118V} = 0.023\%$$

C.)

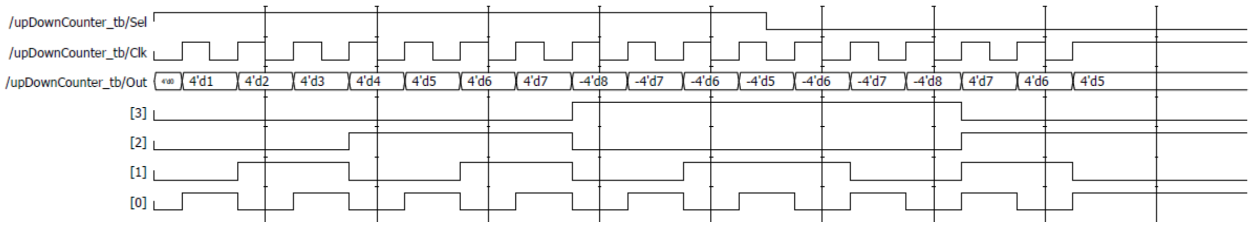
$$V_t = \left(8.617 * 10^{-5}\frac{eV}{K}\right)(301K) = 25.93mV$$

$$I_C = J_s A_E e^{\frac{V_{BE}}{V_t}} = 10^{-14} * 100 * e^{\frac{V_{BE}}{25.93mV}} \rightarrow V_{BE} = 0.537V$$

D.)

Small changes in V_X and T, result in about 1mV change at the output.

Problem 10 and 11



U:/ee330hw11/upDownCounter2.v (/upDownCounter_tb/my_gate) - Default

Ln#

```
`timescale 1ns/1ps
module upDownCounter2(out, sel, clk);
        output [3:0] out;
        input sel, clk;
        reg [3:0] out;
        initial
                out = 0;
        always @(posedge clk)
                if (sel) begin
                        out <= out + 1;
                end else begin
                        out <= out - 1;
                end

endmodule
```

U:/ee330hw11/upDownCounter_tb.v (/upDownCounter_tb) - Default

Ln#

```
`timescale 1ns/1ps
module upDownCounter_tb();
        reg Sel, Clk;
        wire [3:0] Out;
        upDownCounter2 my_gate(.sel(Sel), .clk(Clk), .out(Out));

        initial
        begin
                $monitor(Sel, Clk, Out);
                Clk = 1'b0; Sel = 1'b1;
                #5
                Clk = 1'b1; Sel = 1'b1;
                #5
                Clk = 1'b0; Sel = 1'b1;
                #5
                Clk = 1'b1; Sel = 1'b1;
                #5
                Clk = 1'b0; Sel = 1'b1;
                #5
                Clk = 1'b1; Sel = 1'b1;
                #5
                Clk = 1'b0; Sel = 1'b1;
                #5
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                #5
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                #5
                Clk = 1'b1; Sel = 1'b1;
                #5
                Clk = 1'b0; Sel = 1'b1;
                #5
                Clk = 1'b1; Sel = 1'b1;
                #5
                Clk = 1'b0; Sel = 1'b1;
                #5
                Clk = 1'b1; Sel = 1'b1;
```