ECE 320 - Homework #9

CMOS Logic, Op-Amps, Schmitt Triggers. Due Monday, October 26th

Assume an n-channel MOSFET with the following characteristics:

- Vt = 2V
- Rds = 1 Ohm @ Vgs = 10V @ Ids = 100mA

and a corresponding p-channel MOSFET with

- Vt = -2V
- Rds = 1 Ohm @ Vgs = -10V @ Ids = 100mA

1) Determine the constant Kn

In the Ohmic region

$$I_{ds} = k_n\left(V_{gs} - V_t - \frac{V_{ds}}{2}\right)V_{ds}$$

Plugging in numbers

$$100mA = k_n\left(10V - 2V - \frac{(100mA)(1\Omega)}{2}\right)(100mA)(1\Omega)$$

$$k_n = 0.1258$$

2) Determine the resistance when Vgs = 5V. Assume Ids = 100mA (same as before)

$$100mA = 0.1258\left(5V - 2V - \frac{V_{ds}}{2}\right)V_{ds}$$

$$V_{ds} = 0.2778V$$

and the resistance is

$$R_{ds} = \frac{V_{ds}}{I_{ds}} = 2.778\Omega$$

3) Design a CMOS gate to impliment

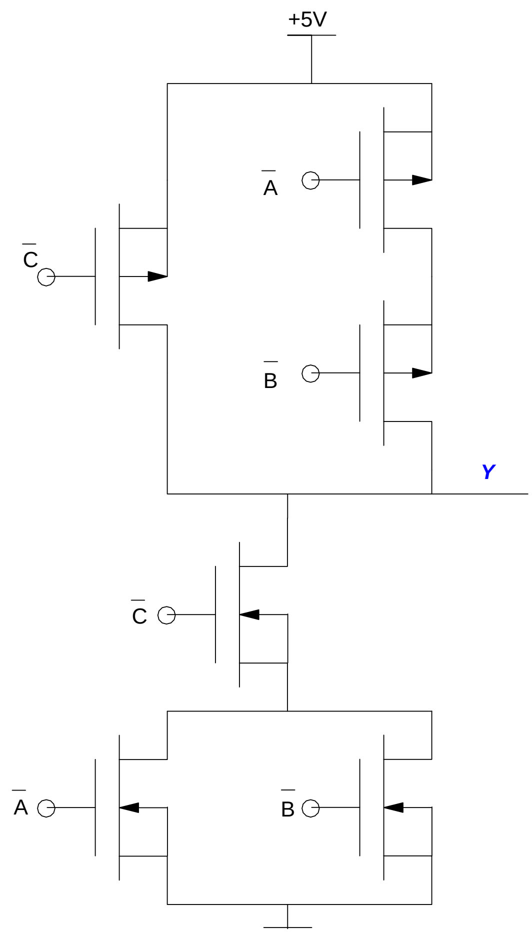
Y = AB+C

On the high-side, the output is pulled high if p-channel MOSFET C or A and B are on. Since 0V turns on the MOSFET, feed these with singnals A' B' and C'

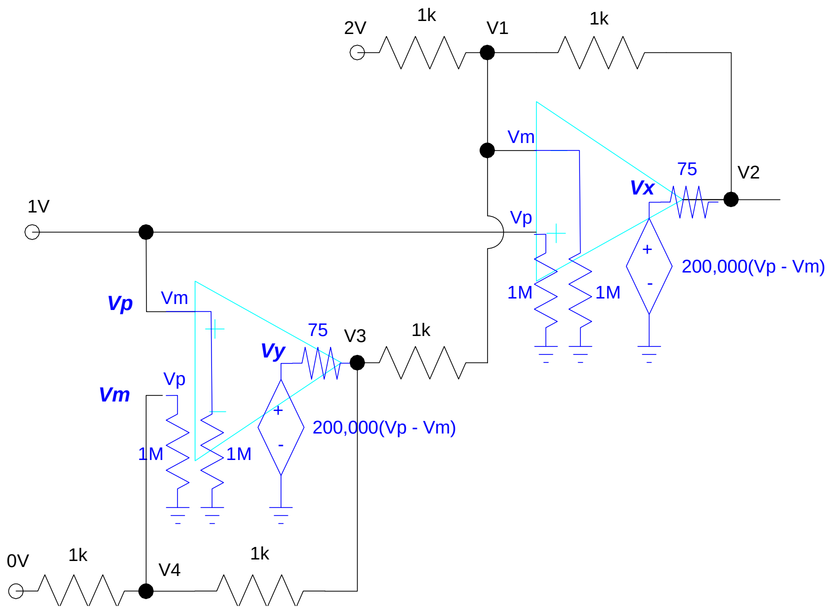
On the low-side, use DeMorgan's theorem

$$\overline{Y} = \overline{C}\left(\overline{A} + \overline{B}\right)$$

The output is pulled low if the n-channel MOSFET is turned on



4) Write the voltage node equations for the following op-amp circuit.



$$\left(\frac{V_1-2V}{1k}\right)+\left(\frac{V_1-V_2}{1k}\right)+\left(\frac{V_1}{1M}\right)+\left(\frac{V_1-V_3}{1k}\right)=0$$

$$\left(\frac{V_2-V_x}{75}\right)+\left(\frac{V_2-V_1}{1k}\right)=0$$

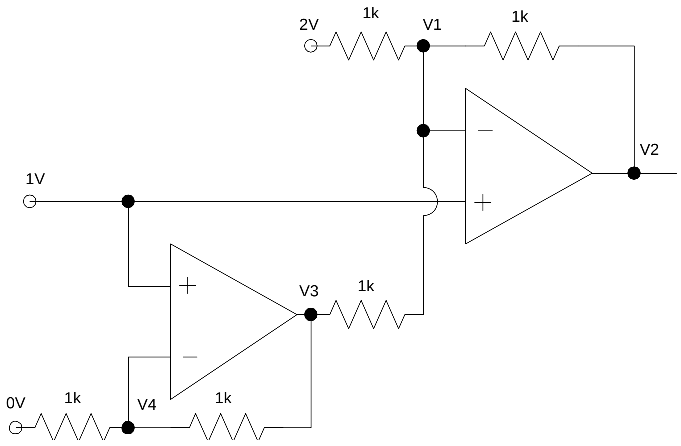
$$V_x=200,000(1-V_1)$$

$$\left(\frac{V_3-V_y}{75}\right)+\left(\frac{V_3-V_1}{1k}\right)+\left(\frac{V_3-V_4}{1k}\right)=0$$

$$V_y=200,000(1-V_4)$$

$$\left(\frac{V_4-0}{1k}\right)+\left(\frac{V_4}{1M}\right)+\left(\frac{V_4-V_3}{1k}\right)=0$$

5) Assume ideal op-amps. Write the voltage node equations for the following op-amp circuit (same as problem 4 but with ideal op-amps)



Start with the equations at V2 and V4: (Vp = Vm)

$$V_1 = 1V$$

$$V_4 = 1V$$

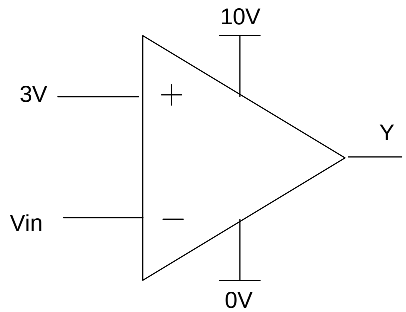
Add in two more equations

$$\left(\frac{V_4}{1k}\right) + \left(\frac{V_4 - V_3}{1k}\right) = 0$$

$$\left(\frac{V_1 - 2}{1k}\right) + \left(\frac{V_1 - V_2}{1k}\right) + \left(\frac{V_1 - V_3}{1k}\right) = 0$$

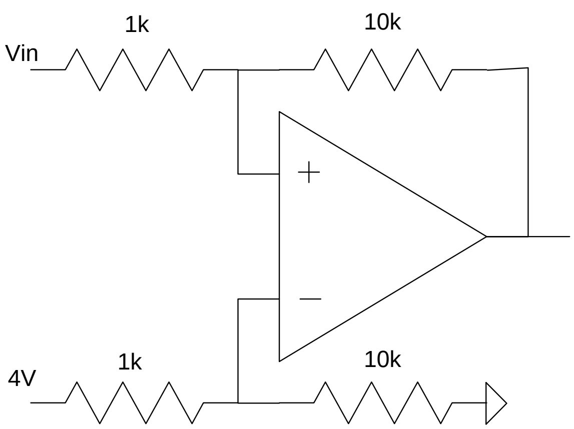
6) Comparitor: Design a circuit which outputs

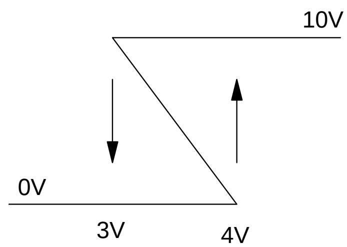
- 10V for Vin < 3V
- 0V for Vin > 3V



7) Schmitt Trigger: Design a circuit which outputs

- 10V when Vin > 4V
- 0V when Vin < 3V
- No change for 3V < Vin < 4V





8) Schmitt Trigger: Design a circuit for a night-light which outputs

- 0V when the light level is more than 10 Lux and
- 10V when the light level is less than 7 Lux

Assume a light sensor with $R = \frac{100{,}000}{Lux}\Omega$

Assume a 10k resistor for the voltage divider

10 Lux: (0V)

R = 10,000 Ohms

Va = 5V

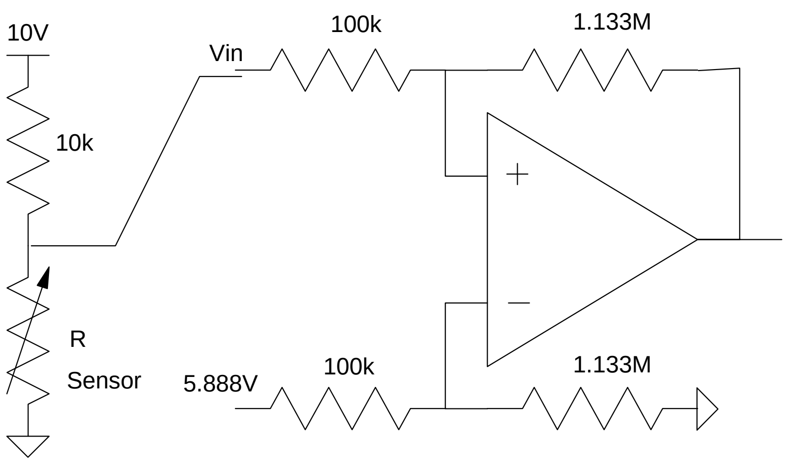
7 Lux: (10V)

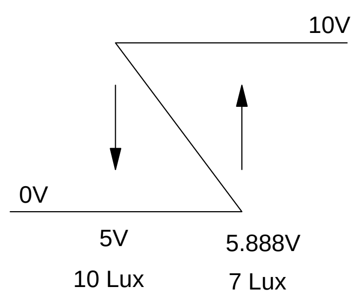
R = 14,258 Ohms

Va = 5.8824V

Gain

$$Gain = \left(\frac{10V - 0V}{5.8824V - 5V}\right) = 11.33$$





Lab: (term project)

Take one section of your term project.

7) Requirements: Specify what your circuit is going to do

- Inputs
- Outputs
- Relationship

8) Analysis. Calculations for votlages, currents, resistors, capacitors, etc

9) Test: Check you analysis in simulation.

10) Validation: Build your circuit and check that it meets the reqruiements.