EC201 : TUTORIAL 5 (CMOS Differential Amplifiers)

Note Title 10/23/2010

For the transistors, assume that

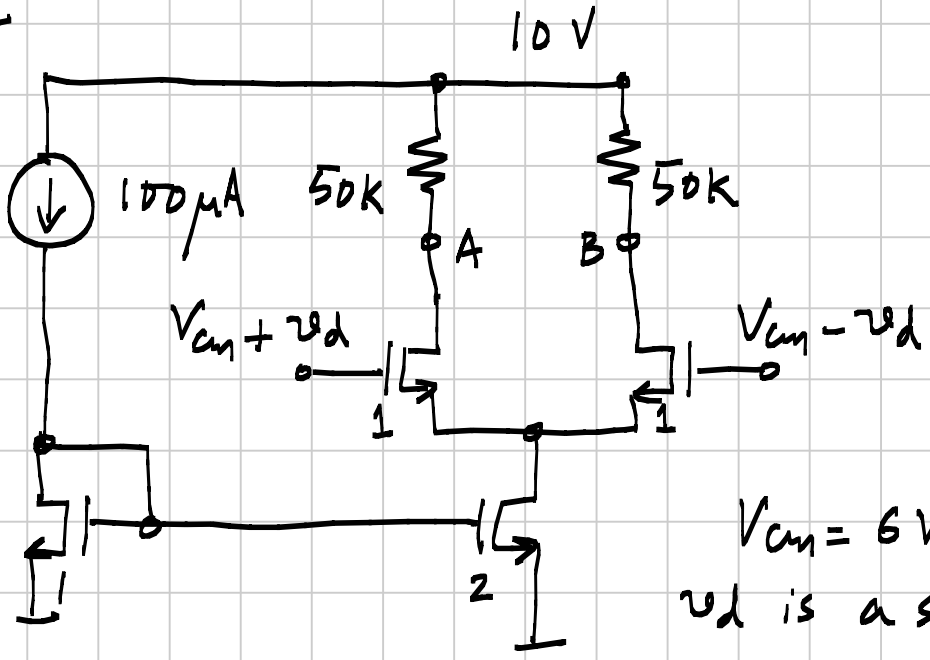
$\mu_n C_{ox} = 200\ \mu A/V^2$ $\quad V_{Tn} = 1V$

$\mu_p C_{ox} = 50\ \mu A/V^2$ $\quad V_{Tp} = 1V$

The W/L is marked beside each device.

$\lambda_n = \lambda_p = 0$, unless otherwise mentioned.

Problem 1:



$V_{cm} = 6V$

v_d is a small signal

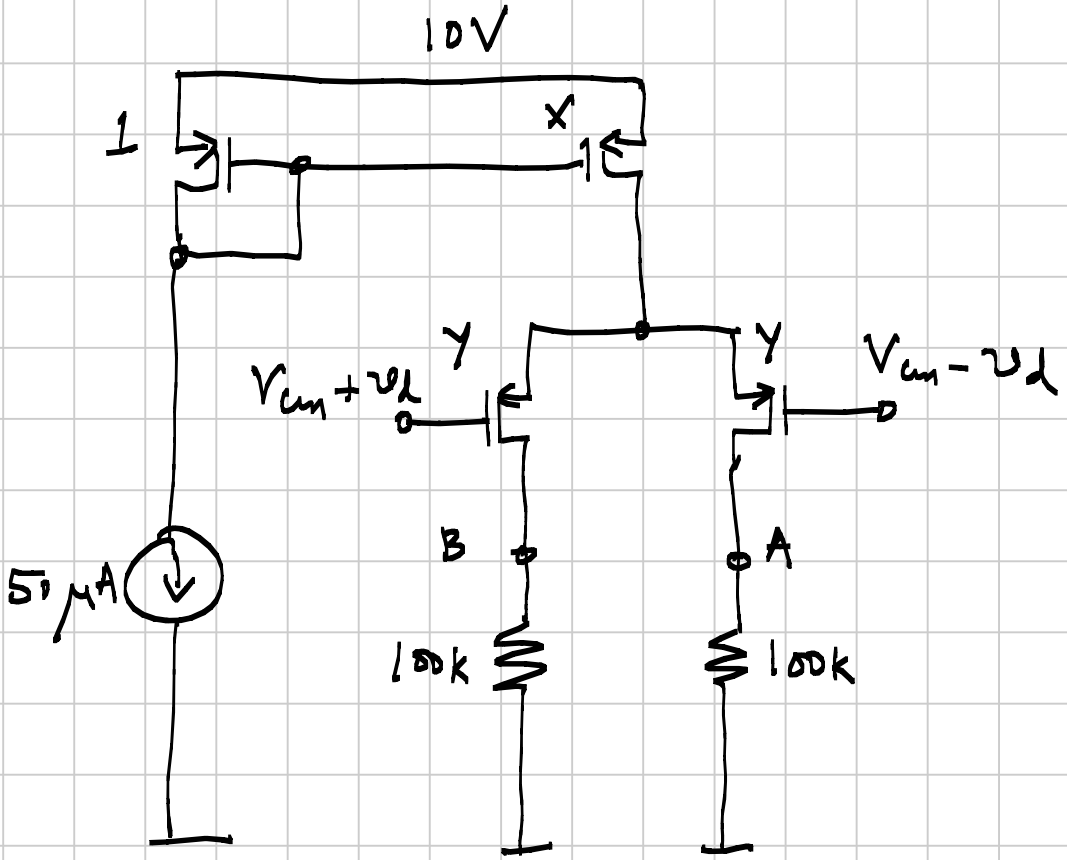
(i) Determine the quiescent voltages at A & B.

(ii) Determine the incremental voltages at A & B.

(iii) Over what range can V_{cm} vary, while still keeping all devices in saturation?

(iv) With $V_{cm} = 6V$, it is desired to increase the incremental gain by increasing the value of the load resistors. What is the maximum value of the gain thus obtainable?

Problem 2:



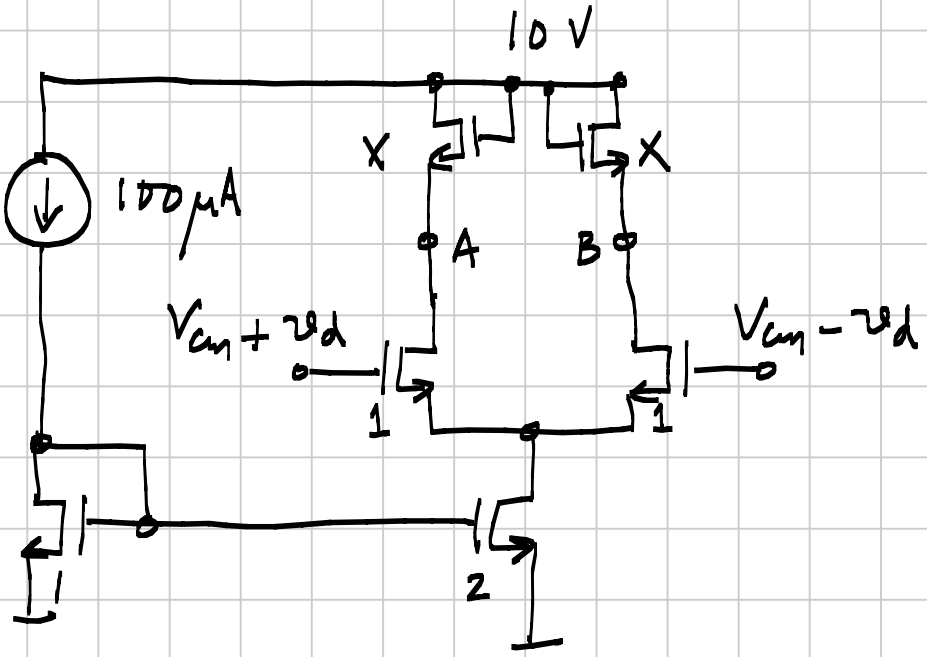
Determine the aspect ratios X & Y so that

(a) The quiescent potentials at A & B are the same as in problem 1

(b) The incremental gain is the same as in problem 1 (assuming all devices are in saturation)

(c) What is the common mode range?

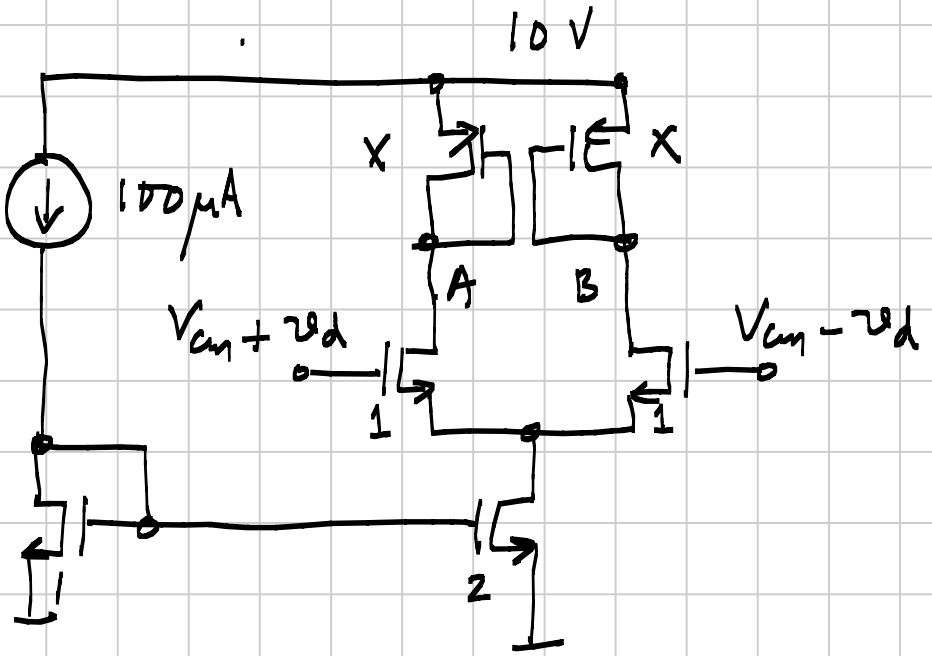
Problem 3:



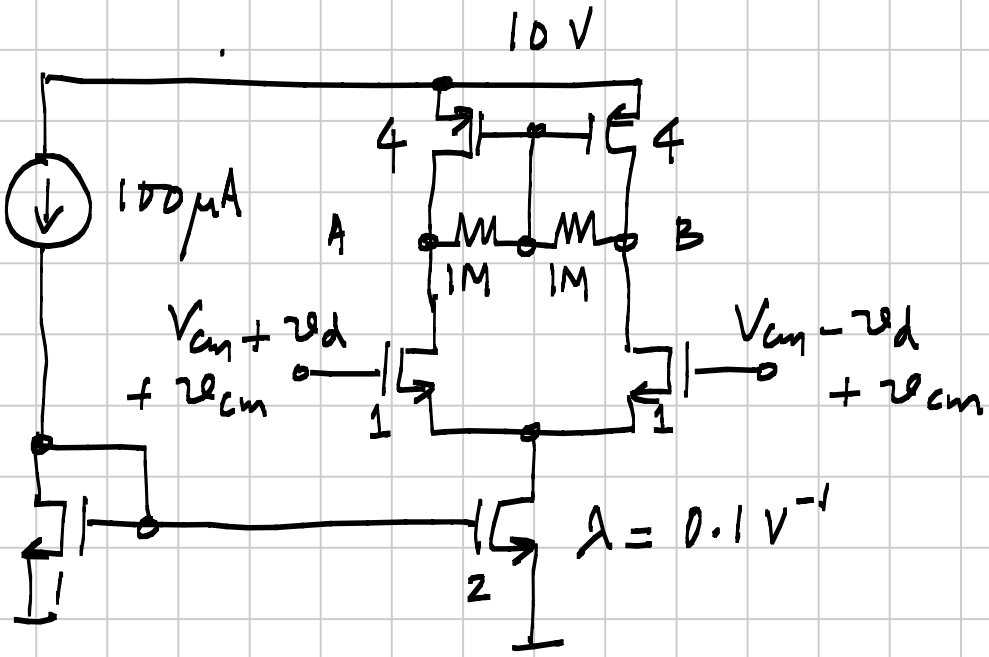
Determine the aspect ratio X, so that the incremental voltage between B & A is $4v_d$. What is the quiescent voltage at A?

Problem 4:

Repeat problem 3 if the load devices were PMOS transistors as shown below.



Problem 5:



$V_{cm} = 5V$

v_{cm} & v_d are small signals. Only for the tail current source, use $\lambda = 0.1\,V^{-1}$. Neglect λ to find the quiescent operating point.

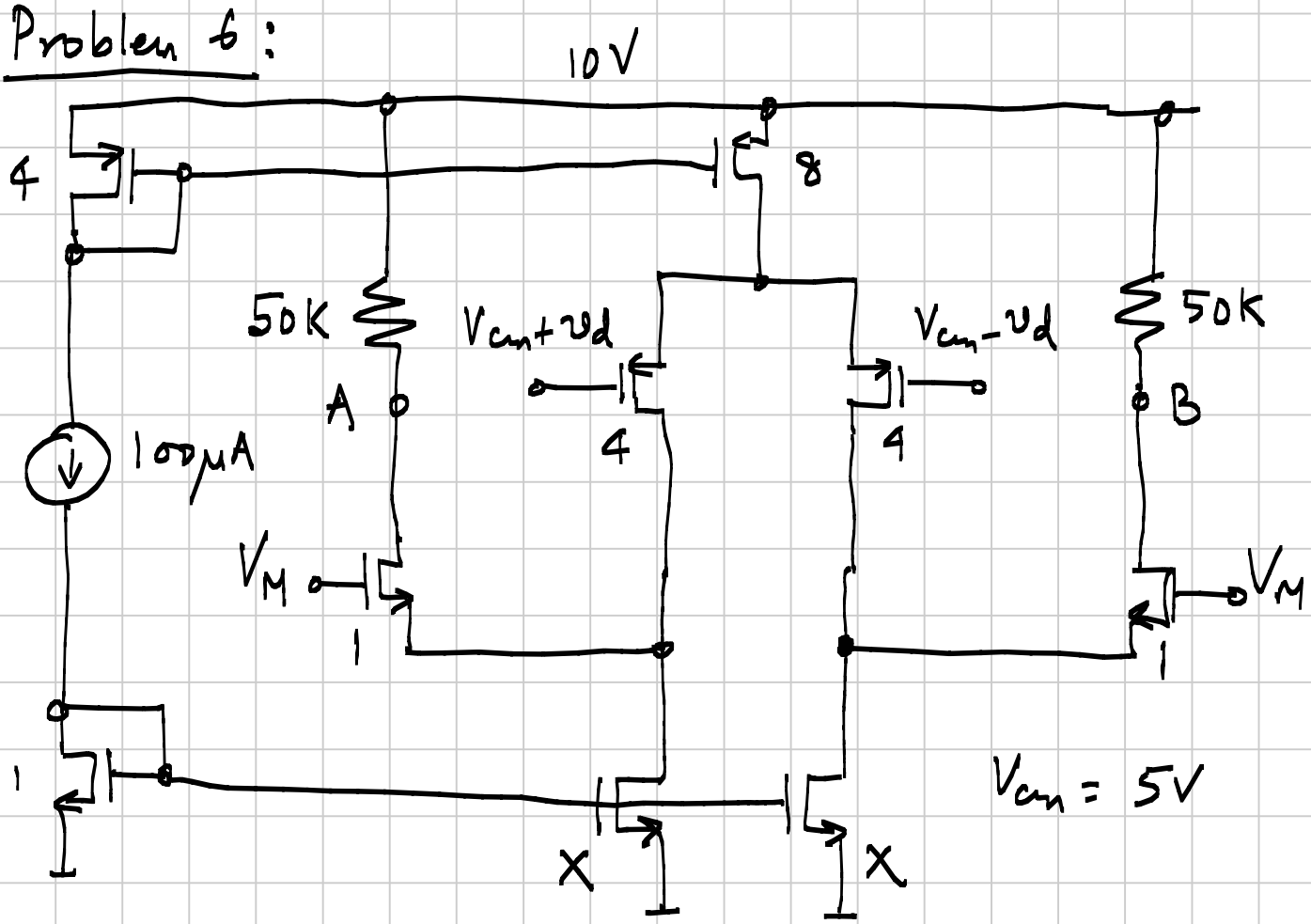
(a) Determine the quiescent potentials at A & B.

(b) Determine the incremental voltages at A & B.

(c) What is the common-mode rejection ratio?

(d) What is the common-mode range?

Problem 6:



(a) Assuming all devices are in saturation, determine X so that the quiescent voltage at A & B is 5V.

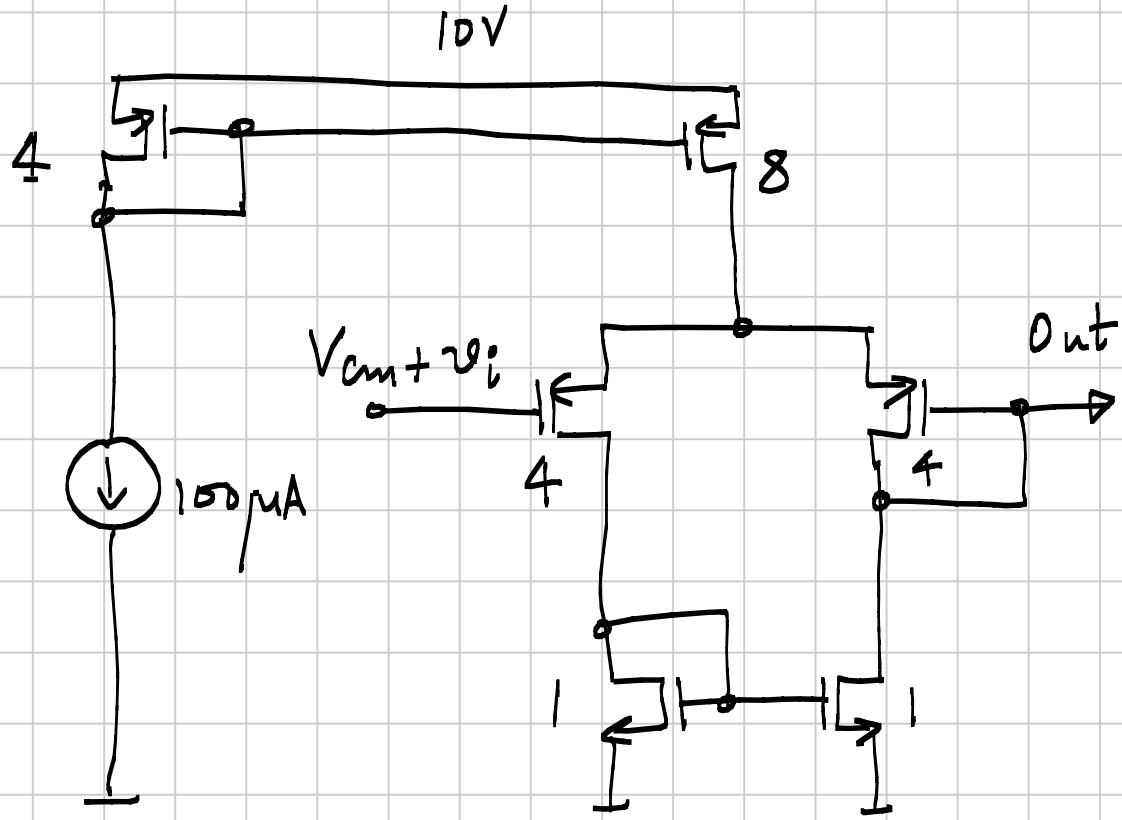
(b) For the value of X you just determined, find the range of V_M over which all devices remain in saturation.

(c) For V_M = 3V, determine the range over

which V_{cm} can vary while keeping all devices in saturation.

(d) What is the incremental gain $v_{BA}/2v_d$?

Problem 7:

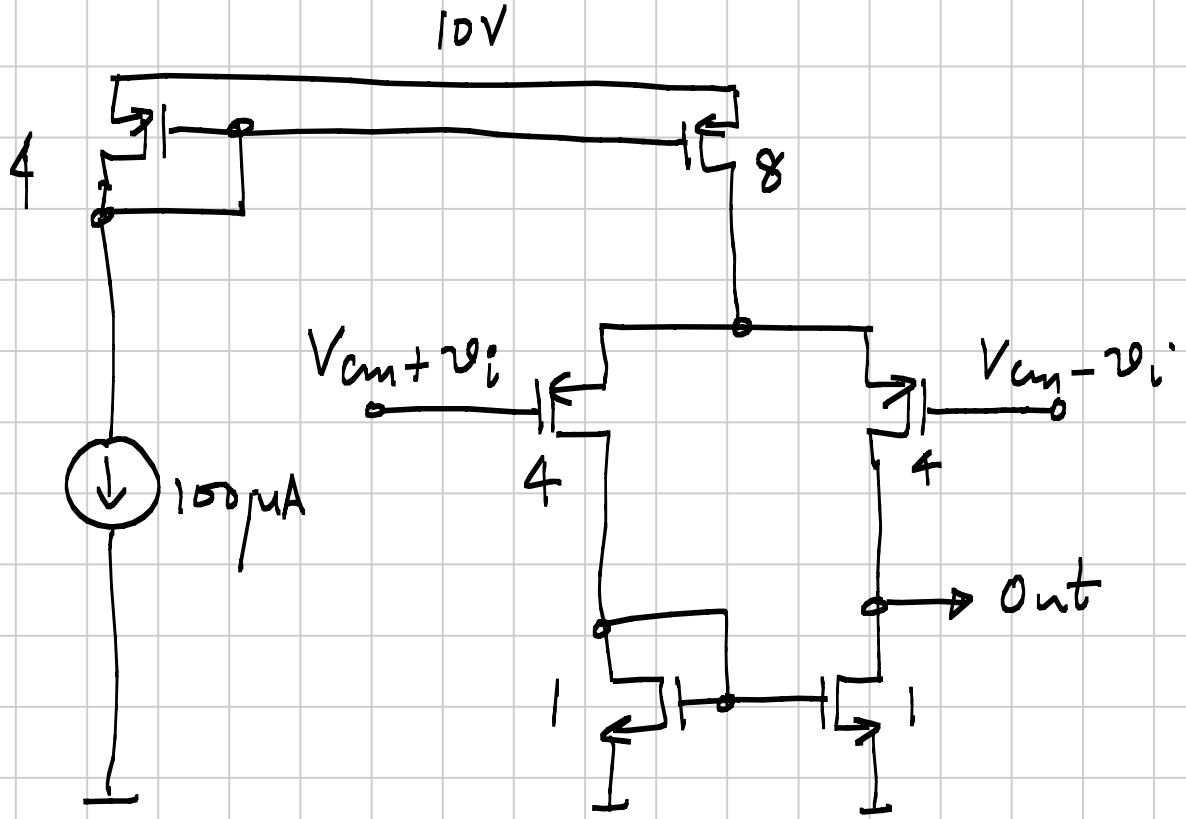


$V_{cm} = 5\,V$

(i) Determine the incremental gain from input to output.

(ii) Over what range of V_{cm} is this gain maintained ?

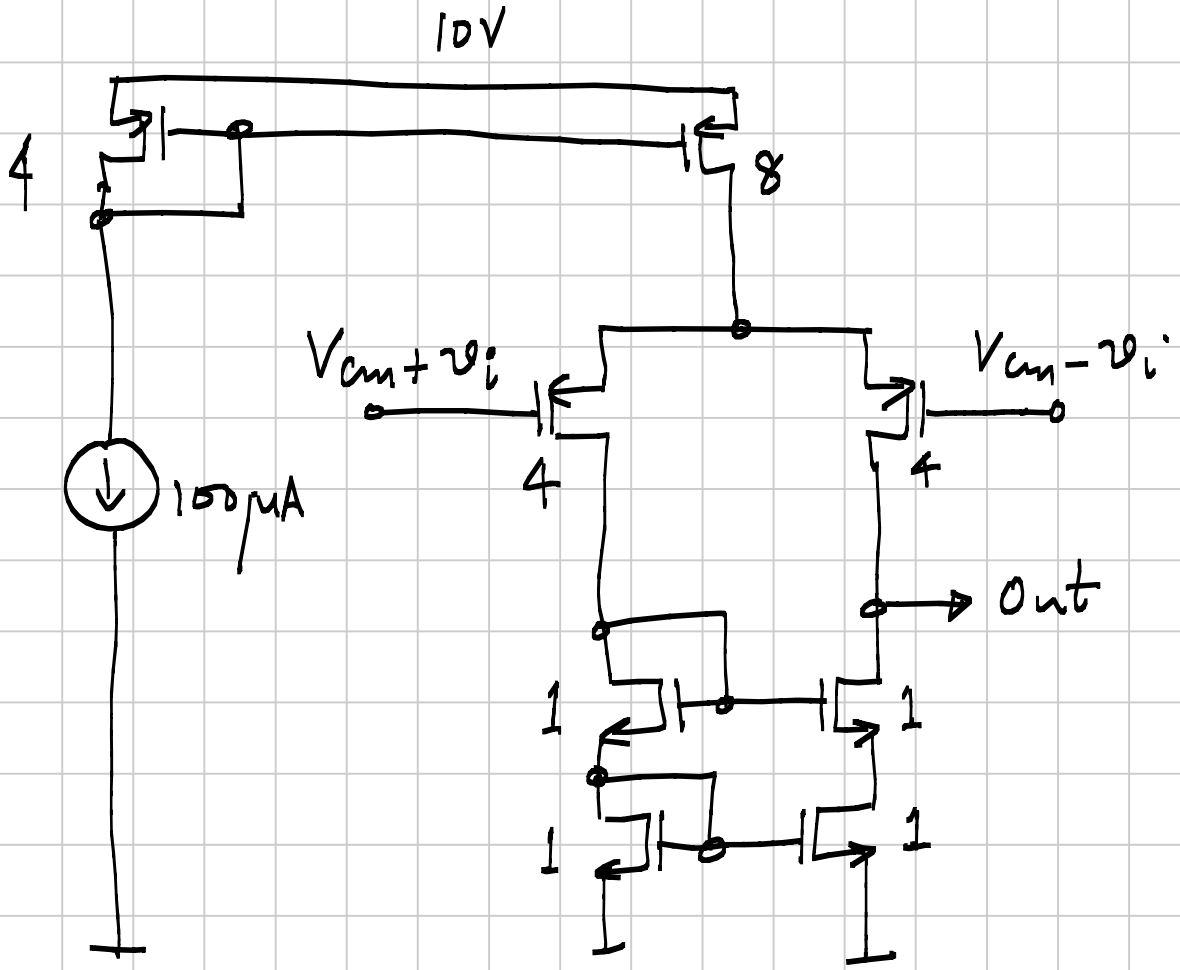
Problem 8 :



$\lambda_p = 0$, $\lambda_n = 0.1\,V^{-1}$ $V_{cm} = 5\,V$

(a) Determine the incremental output voltage in the circuit above.

(b) Now, repeat the above exercise for the Circuit shown below.



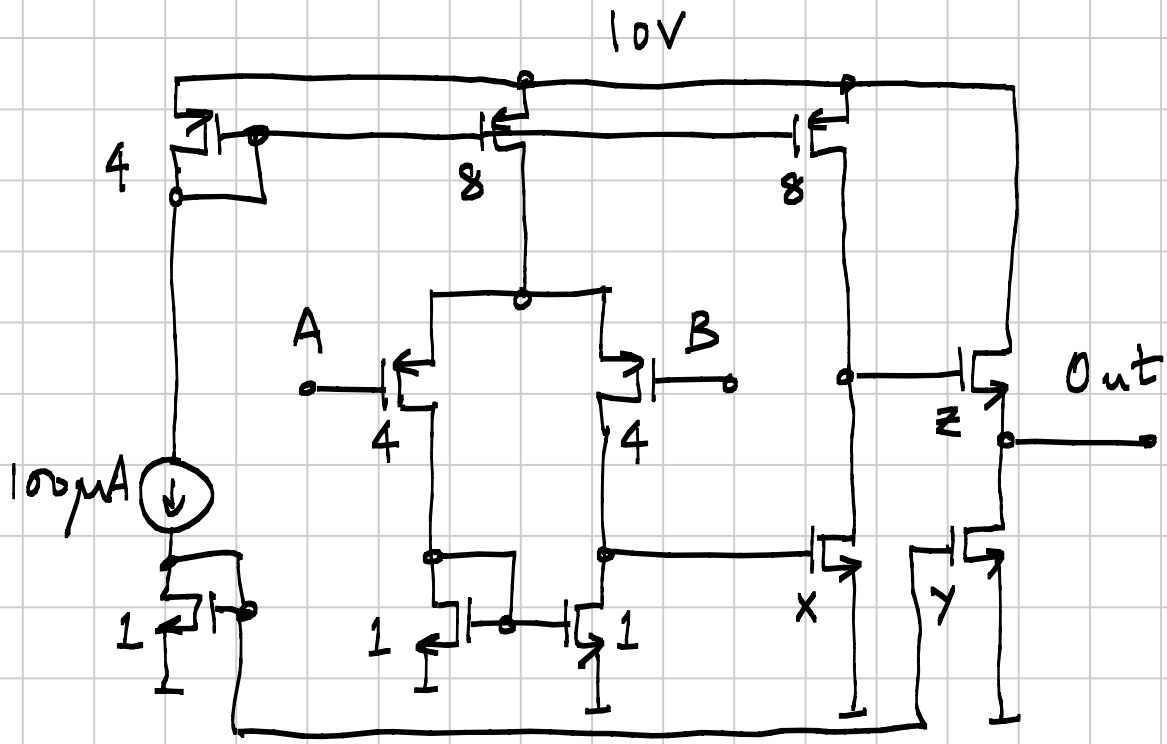
$\lambda_p = 0$, $\lambda_n = 0.1V^{-1}$ $V_{cm} = 5V$

Problem 9

Shown below is the circuit diagram of an opamp.

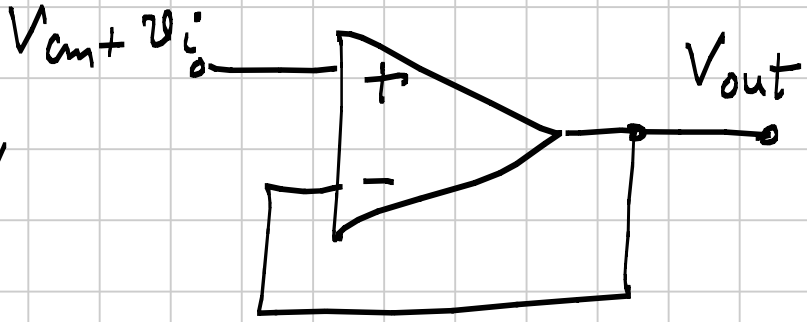
(a) Find which of the terminals A, B is the noninverting input.

(b) It is desired that, when all the devices are in saturation, the quiescent potentials at the drains of the input devices are equal. Find X.



(c) The output of the opamp should be able to sink in 1 mA. Further, the output resistance should be 500 Ω. Determine Y & Z for this to happen.

(d) The opamp above is hooked up as a unity gain buffer as shown below.



$V_{cm} = 5V$

Determine the incremental gain and output impedance of the buffer.

Find the maximum input amplitude that results in a distortion free output.

Repeat when the buffer is loaded with load resistors 5k and 500 Ω.

What do you notice ?