B. INS. & ELEC. ENGINEERING 3RD YEAR 2ND SEMESTER EXAMINATION 2022

ANALOG MOS CIRCUIT DESIGN

FULL MARKS: 100

TIME: 3 HOURS

List of Course Outcomes (CO):

CO1: Classify and analyze different types of MOS amplifiers (K4, A1-recognize).

CO2: Explain and interpret the importance of differential amplifiers (K3, A1)

CO3: Describe and explain the behavior of current mirrors (K2, A1)

CO4: Explain and analyze the frequency response of MOS amplifiers (K4, A1)

Instructions to the Examinees:

- Each module is mapped with the corresponding CO
- Attempt questions from **ALL** the modules
- Alternative questions exist within a module, not across the modules
- -Different parts of same question should be answered together
- Clearly state any assumption and derive the necessary equation(s) for calculation
- Unless otherwise stated, use the device data shown in Table I and assume $V_{DD} \doteq 3\,V$ where necessary

Table I

Symbol	Value	Unit
$V_{th,n}$	0.7	V
$V_{th,p}$	−0.8	V
γ_n	0.45	$V^{1/2}$
γ_p	0.4	$V^{1/2}$
$\mu_n C_{ox}$	50	$\mu A/V^2$
$\mu_p C_{ox}$	25	$\mu A/V^2$
λ_n	0.1	V^{-1}
λ_p	0.2	V^{-1}

MODULE 1

(ATTEMPT ANY FOUR FROM THE FOLLOWING)

1.

(a) Write down the condition for a p-MOS device to operate in the saturation region.

(b) Sketch I_X and trans-conductance of the transistor as a function of V_X for the circuit in Fig. 1 as V_X varies from 0 to V_{DD}.

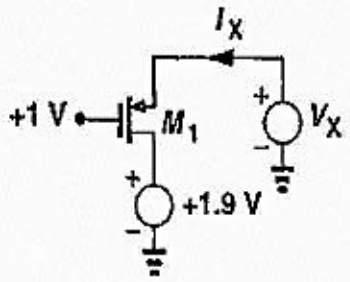

Fig. 1

2+8

2.

(a) What do you understand by body effect? How does it affect the threshold voltage of MOSFET?

(b) Draw the MOS small-signal model by taking channel-length modulation and body effect into your consideration.

(c) Sketch g_m and g_{mb} as a function of the bias current I_1 in Fig. 2.

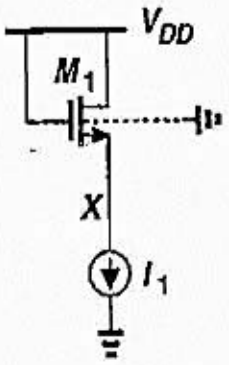

Fig. 2

3+2+5

3. Draw and explain the transfer characteristics of the circuit shown in Fig. 3. Sketch the drain current and trans-conductance of the MOS device as a function of the input voltage.

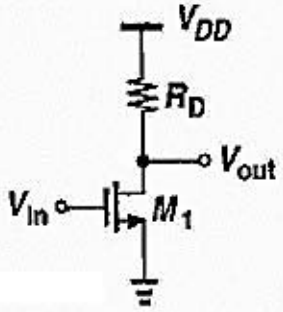

Fig. 3

10

4. Sketch v_{out} versus v_{in} for the circuit in Fig. 4 as v_{in} varies from 0 to V_{DD}. Identify the important transition points.

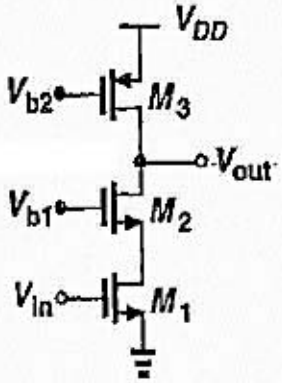

Fig. 4

10

5. Calculate the voltage gain of the circuit shown in Fig. 5. Assume $\lambda \neq 0$ and $\gamma \neq 0$

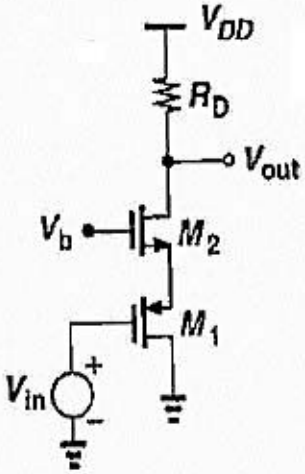

Fig. 5

10

MODULE 2

(ATTEMPT ANY THREE FROM THE FOLLOWING)

6.

(a) What do you mean by differential signals?

(b) Show that the equivalent G_m for a differential amplifier falls to zero for $\Delta v_{in} = \sqrt{\frac{2I_{SS}}{\mu_n C_{ox}\frac{W}{L}}}$, where the symbols enjoy their usual significances.

2+8

7.

(a) What is the significance of tail current source in a differential amplifier? Explain.

(b) Plot the input-output characteristics of a differential pair as the device width and tail current vary.

(c) How is the input common-mode level of a differential amplifier limited?

3+5+2

8. A differential pair uses input NMOS devices with $W/L = 50/0.5$ and a tail current of $1\,mA$. What is the equilibrium overdrive voltage of each transistor? How is the tail current shared between two sides if $v_{in1} - v_{in2} = 50\,mV$? What is the equivalent G_m under this condition?

10

9.

(a) Under which condition a common mode input signal produces non-zero differential output? Explain.

(b) Find out the expression for differential gain by considering mismatches in trans-conductance of two MOS devices and non-ideal tail current source.

3+7

MODULE 3

(ATTEMPT Q. NO. 9 AND ANY ONE FROM THE REST)

10. Find out the drain current of M_4 in Fig. 6 if all of the transistors are in saturation.

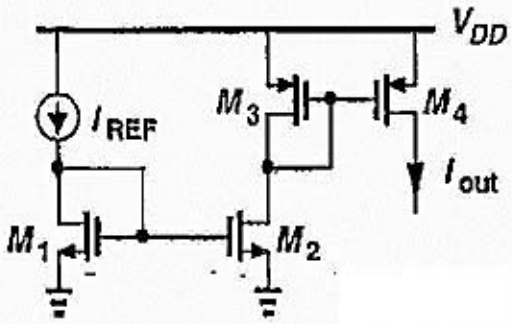

Fig. 6

8

11. In Fig. 7, assuming all of the transistors are identical, sketch I_X and V_B as V_X drops from a large positive value.

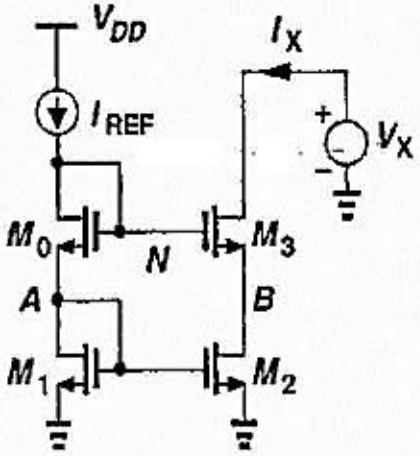

Fig. 7

12

12. In Fig. 8, sketch V_X and V_Y as a function of I_{REF}. If I_{REF} requires 0.5V to operate as a current source, what is its maximum value?

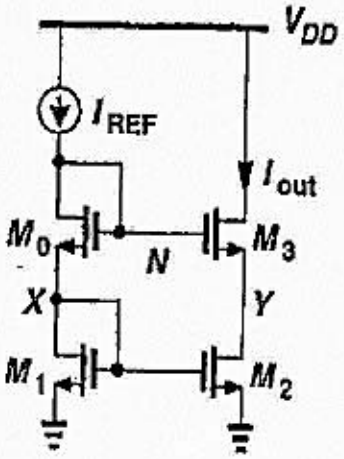

Fig. 8

12

MODULE 4

(ATTEMPT ANY ONE FROM THE FOLLOWING)

13. Calculate the transfer function of the circuit shown in Fig. 9.

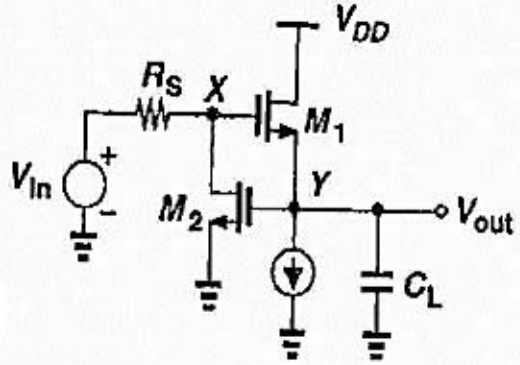

Fig. 9

10

14. Estimate the poles of the circuit in Fig. 10 below.

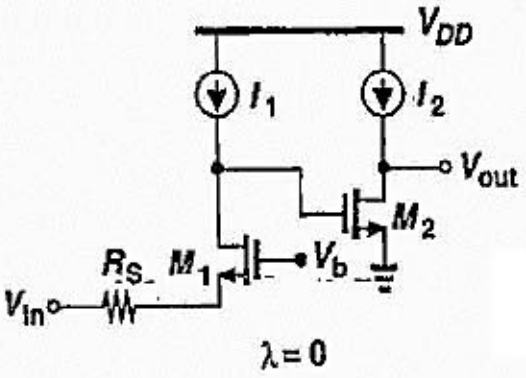

Fig. 10

10

----------X----------