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M. TECH INS. & ELEC. ENGINEERING 1ST YEAR 1ST SEMESTER EXAMINATION 2025

DESIGN OF ANALOG CMOS INTEGRATED CIRCUITS

TIME: 3 HOURS **FULL MARKS: 100**

List of Course Outcomes (CO):

CO1: Design and analyze MOS-based amplifier circuits.

CO2: Understand the principle of current mirror circuits.

CO3: Explain the frequency response behavior of MOS-based circuits.

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 $V_{DD} = 3\ V$ 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}

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MODULE 1

(ATTEMPT ANY **FOUR** QUESTIONS FROM THE FOLLOWING)

1.

(a) Derive the current-voltage characteristics of a MOSFET.

(b) Plot the variation of trans-conductance as a function of drain to source voltage when the MOSFET is driven by a constant gate voltage.

10+5

2.

(a) Terminal voltages for the MOS in Fig. 1 at G, D, S and B are given by 0.8 V, 0.9 V, 0.1 V and 0 V respectively. What is the status of the MOSFET? Explain.

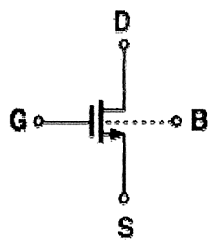

Fig. 1

(b) Sketch I_X and trans-conductance of the MOS as a function of V_X for the circuit in Fig. 2 as V_X varies from 0 to V_{DD}.

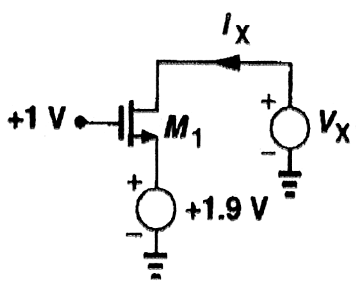

Fig. 2

5+10

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3.

(a) Draw and explain the large signal behavior of the circuit in Fig. 3. Hence, calculate its small signal voltage gain.

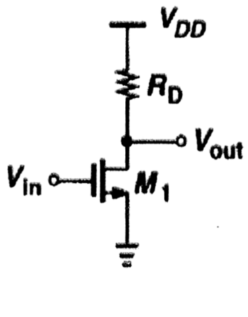

Fig. 3

(b) Redesign the circuit in Fig. 3 so that its voltage gain can be increased.

(8+3)+4

4.

(a) Draw the diagram of a degenerated current source and hence find out its resistance.

(b) Calculate the voltage gain of the circuit shown in Fig. 4 below. Assume $\lambda \neq 0$ and $\gamma = 0$.

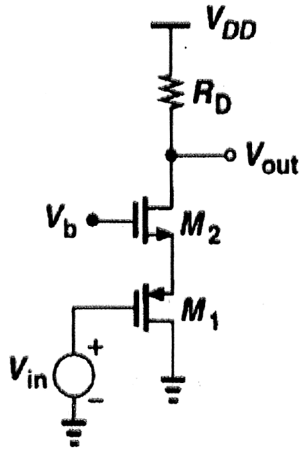

Fig. 4

6+9

5.

(a) What is the advantage of differential amplifier over a single ended amplifier?

(b) Show that the equivalent trans-conductance of a symmetric differential amplifier is given by:

$$G_m = \frac{1}{2}\mu_n C_{ox}\frac{W}{L}\frac{\frac{4I_{SS}}{\mu_n C_{ox}\frac{W}{L}} - 2\Delta v_{in}^2}{\sqrt{\frac{4I_{SS}}{\mu_n C_{ox}\frac{W}{L}} - \Delta v_{in}^2}}$$

, where the symbols enjoy their usual significances.

3+12

6.

(a) Draw the schematic diagram of a current-shunt feedback amplifier.

(b) Using MOSFETs, design the circuit diagram of a voltage-series feedback amplifier. Hence, find out its gain with feedback and feedback factor.

5+(5+5)

MODULE 2

(ATTEMPT **Q. NO.** 7 AND ANY **TWO** QUESTIONS FROM THE REST)

7. Select **one or more** correct option(s) from the choices given below:

(a) Current mirror circuits can be constructed using

- (i) n-MOS only
- (ii) p-MOS only
- (iii) Both n-MOS and p-MOS in the same circuit
- (iv) Both n-MOS and p-MOS in different circuits

(b) Cascode current mirror circuit is used to

- (i) Suppress the effect of channel length modulation
- (ii) Improve the voltage headroom
- (iii) Minimize the requirement of MOS transistors
- (iv) Reduce the power consumption

(c) Active current mirrors are those which

- (i) Carry bias current only
- (ii) Carry time varying current
- (iii) Do not carry any current through it
- (iv) None of the above

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8. Design one cascode current mirror circuit and hence explain how it can copy the current from a reference current source. Calculate the available voltage swing resulting from the circuit.

8+2

9. In Fig. 5, 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?

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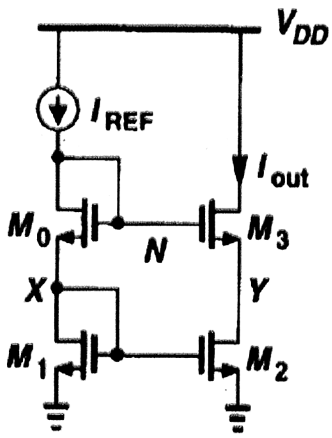

Fig. 5

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10. Show that the common-mode gain of the circuit in Fig. 6 with g_m mismatch is approximately given by:

$$\frac{\Delta V_{out}}{\Delta V_{in,CM}} \approx \frac{(g_{m1} - g_{m2})r_{o3} - \left(\frac{g_{m2}}{g_{m3}}\right)}{1 + (g_{m1} + g_{m2})R_{SS}}$$

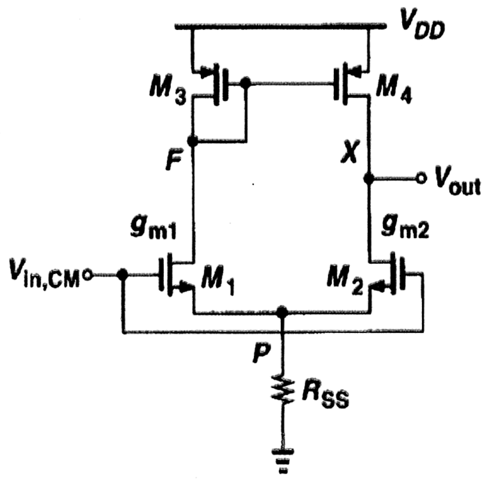

Fig. 6

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MODULE 3

11. Draw the high frequency small signal model of the amplifier shown in Fig. 7 below.

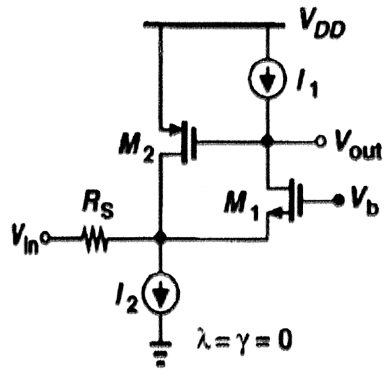

Fig. 7

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12. Find out the transfer function of a source follower circuit driven by resistive load only.

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