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ECE Box # _____

Problem	Score	Points
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1	_____	30
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2	_____	30
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3	_____	20
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4	_____	20
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EE4902 C2002

Analog IC Design

Exam 2

- This is a **closed book test!**
- Show **all** your work. Partial credit may be given. If you think you need something that you can't remember, write down what you need and what you'd do if you remembered it.
- **Look for the simple, straightforward way to solve the problem for the level of accuracy required. Don't get entangled in unnecessary algebra.**
- You may assume all op-amps to be ideal, except as otherwise noted.
- As in real life, some problems may give you more information than you need. Don't assume that all information must be used! It's your job to decide what's relevant to the solution.
- You have until 12 noon to complete this exam. There are four problems on a total of 13 pages.

MOSFET LARGE SIGNAL CHARACTERISTICS

	N CHANNEL	P CHANNEL
CIRCUIT SYMBOL		
ACTIVE	$I_D = \frac{\mu_n C_{ox}}{2} \frac{W}{L} \underbrace{(V_{GS} - V_{tn})^2}_{V_{eff}^2} [1 + \lambda_n (V_{DS} - V_{eff})]$	$I_D = \frac{\mu_p C_{ox}}{2} \frac{W}{L} \underbrace{(V_{SG} + V_{tp})^2}_{V_{eff}^2} [1 + \lambda_p (V_{SD} - V_{eff})]$
I_D - V_{DS} CHARACTERISTIC		
I_D - V_{GS} CHARACTERISTIC (ACTIVE REGION)		
TRIODE REGION	$I_D = \mu_n C_{ox} \frac{W}{L} \left[(V_{GS} - V_{tn})V_{DS} - \frac{V_{DS}^2}{2} \right]$	$I_D = \mu_p C_{ox} \frac{W}{L} \left[(V_{SG} + V_{tp})V_{SD} - \frac{V_{SD}^2}{2} \right]$

1. This problem involves design of a common source amplifier circuit with active load. The circuit is shown in Figure 1a.

You may assume that the substrate (body) terminal is tied to the source terminal.

Use the following MOSFET parameters for this $2\mu\text{m}$ process:

Parameter	N-channel	P-channel	Units
V_t	+1.10	-1.20	V
μC_{ox}	5.2E-5	1.5E-5	A/V ²
λ	0.03	0.02	V ⁻¹

- a) Choose R_B for a current of $I_B=200\mu\text{A}$ in the current mirror.

[4]

$$R_B = \underline{\hspace{2cm}}$$

- b) Choose the input bias voltage V_{BIAS} to achieve an output voltage in the linear range (both M1 and M2 in the active region).

[4]

$$V_{BIAS} = \underline{\hspace{2cm}}$$

- c) Determine the magnitude of the low-frequency small-signal gain from v_{in} to v_{out} .

[8]

$$|a_v| = \left| \frac{v_{out}}{v_{in}} \right| =$$

- d) Determine the maximum and minimum output voltages for both M1 and M2 to be in the active region.

[4]

$$V_{OUT(MAX)} = \underline{\hspace{2cm}}$$

$$V_{OUT(MIN)} = \underline{\hspace{2cm}}$$

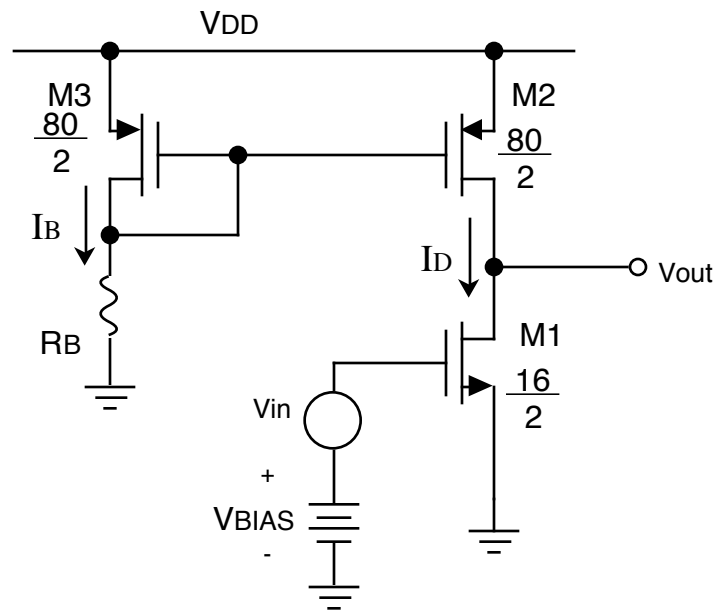


Figure 1a.

*** MORE ON THE NEXT PAGE !!! ***

A load impedance of $150\text{k}\Omega \parallel 20\text{pF}$ is added to the output as shown in Figure 1b.

- e) Will the low-frequency small signal gain magnitude $|a_v|$ decrease, remain the same, or increase?

[1]

DECREASE

SAME

INCREASE

EXPLAIN!

[4]

- f) Determine the DC gain and 3-dB bandwidth frequency ($f_{3\text{-dB}}$) for the circuit with the load impedance of $150\text{k}\Omega \parallel 20\text{pF}$ added to the output.

[5]

DC gain = _____

$f_{3\text{-dB}}$ = _____

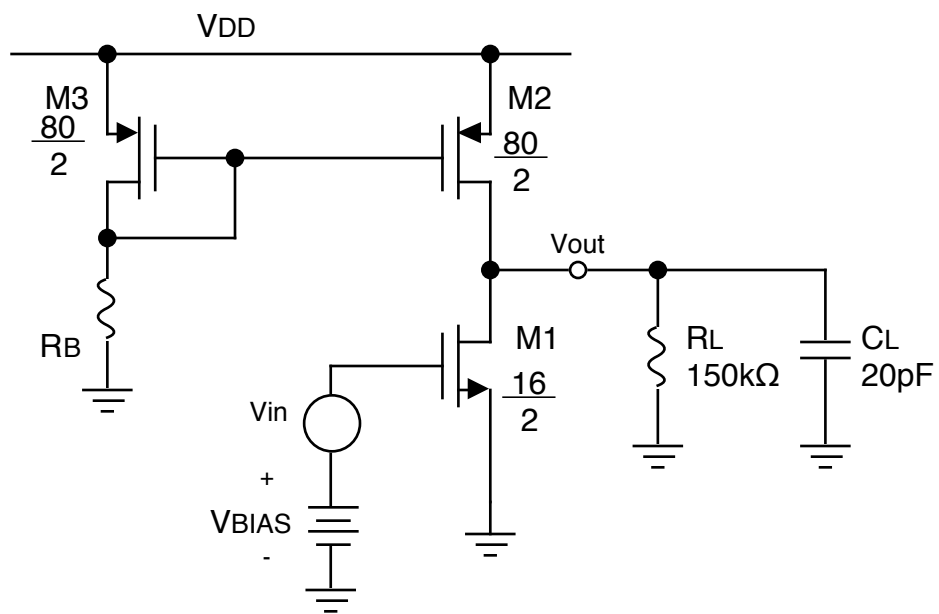


Figure 1b.

This problem concerns the design of the differential amplifier shown in Fig. 2.

You may assume that the substrate (body) terminal is tied to the source terminal. You may also ignore channel length modulation (assume $\lambda=0$)

Use the following MOSFET parameters for this $2\mu\text{m}$ process:

Parameter	N-channel	P-channel	Units
V_t	+1.10	-1.20	V
μC_{ox}	5.2E-5	1.5E-5	A/V ²

- a) Choose I_{BIAS} for an output DC bias level of $V_{O1(DC)} = V_{O2(DC)} = +3.0\text{V}$.

[4]

$$I_{BIAS} = \underline{\hspace{2cm}}$$

- b) Determine the magnitude of the low-frequency small-signal **differential mode** gain $|a_{v(dm)}|$ from input $v_+ - v_-$ to output $v_{o1} - v_{o2}$.

[8]

$$|a_{v(dm)}| = \left| \frac{v_{out(dm)}}{v_{in(dm)}} \right| = \left| \frac{v_{o1} - v_{o2}}{v_+ - v_-} \right| =$$

- c) Determine the magnitude of the low-frequency small-signal **common mode** gain $|a_{v(cm)}|$ from input v_{cm} to output v_{o1} or v_{o2} .

[8]

$$|a_{v(cm)}| =$$

Your design from the previous problem is modified by splitting the bias current source and inserting resistor R_s between the sources of M1 and M2, as shown in Figure 3b.

- a) Will the magnitude of common mode gain $|a_{v(cm)}|$ decrease, remain the same, or increase? [1]

DECREASE

**REMAIN
THE SAME**

INCREASE

EXPLAIN! [6]

- b) Will the magnitude of the differential mode gain $|a_{v(dm)}|$ decrease, remain the same, or increase? [1]

DECREASE

**REMAIN
THE SAME**

INCREASE

EXPLAIN! [6]

- c) Determine the magnitude of the differential mode gain $|a_{v(dm)}|$. [6]

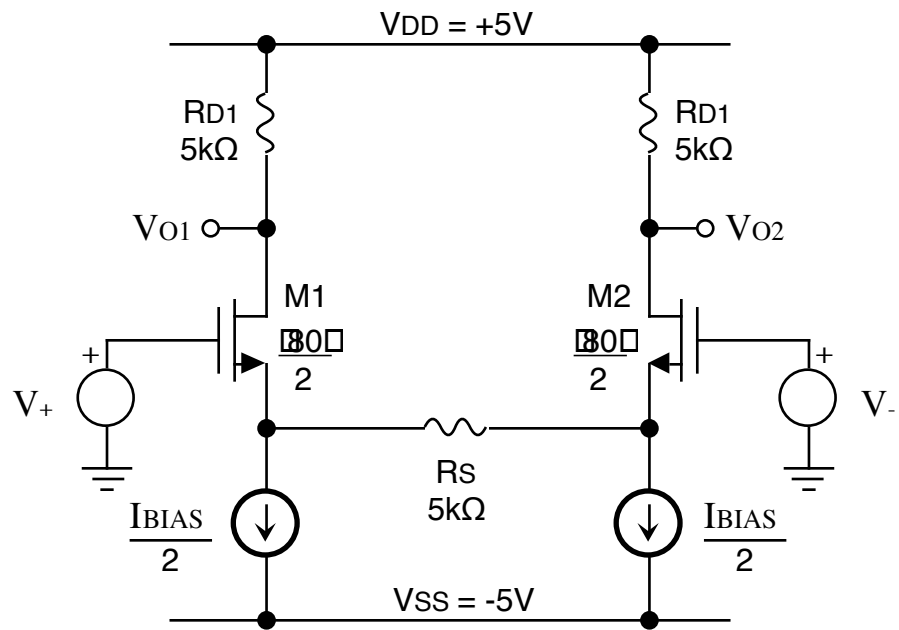


Figure 3b.

4. The Common Gate Amplifier, or “Trust the small-signal model, Luke”

The input impedance of the common source amplifier is (ideally) infinite, since the input voltage “sees” only the MOSFET gate terminal, which draws essentially no gate current due to the gate oxide. This high input impedance is usually an advantage, but in some high-frequency applications it is desired to have a relatively low input impedance. For example, in some RF circuit design applications, the amplifier input impedance can be used to match the characteristic impedance of a transmission line. Figure 4 shows the common gate amplifier, which is often used in this type of application.

You may assume that the substrate (body) terminal is tied to the source terminal. You may also assume channel length modulation to be negligible ($\lambda=0$).

Use the following MOSFET parameters for this process:

Parameter	N-channel	P-channel	Units
V_t	+1.10	-1.20	V
μC_{ox}	5.2E-5	1.5E-5	A/V ²

- a) Using the space on the following page, draw the low-frequency small-signal model for this amplifier circuit.

[8]

- Determine $|a_v|$, the magnitude of the low-frequency small-signal gain from v_{in} to v_{out} .

[6]

$$|a_v| = \left| \frac{v_{out}}{v_{in}} \right| = \underline{\hspace{2cm}}$$

- c) Determine r_{in} , the small-signal input resistance looking into the input at the source terminal of the MOSFET.

[6]

$$r_{in} = \underline{\hspace{2cm}}$$

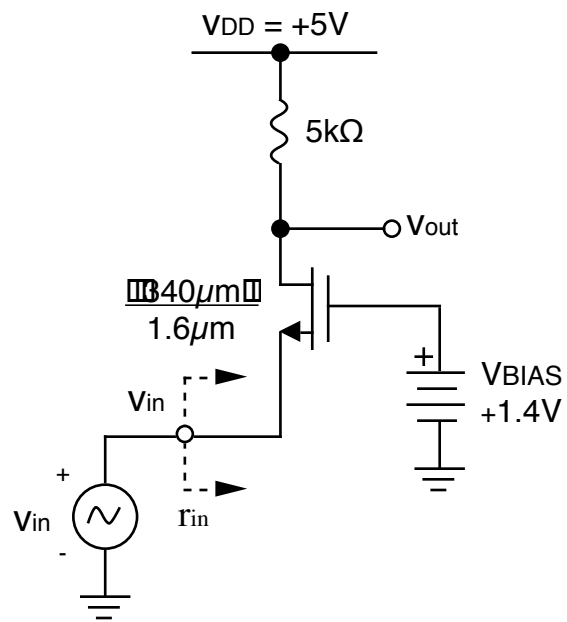


Figure 4.

Small signal model for part (a):