Simon Fraser University

Mechatronic Systems Engineering

Final Exam for ENSC 226: Electronic Circuits

Instructor: Behraad Bahreyni

16 April 2012

Time: 150 minutes

Name: ______________________

Student number: ______________

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All writing must be submitted with this examination booklet (notes, drafts, calculations, etc.). This booklet must not be torn or mutilated in any way, and must not be taken from the examination room.

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Question	Mark
1	/ 10
2	/ 15
3	/ 20
4	/ 20
5	/ 20
6	/ 10
7	/ 15
Total	/110

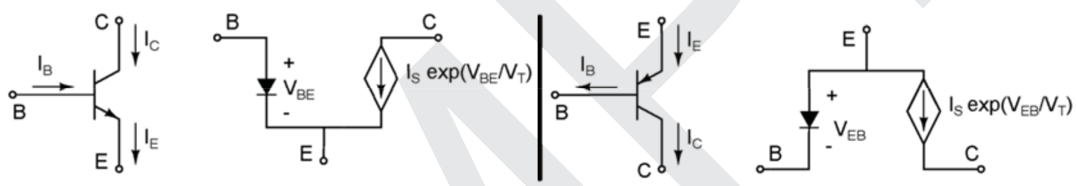
Physical model of a diode: $I_D = I_s\left(e^{\frac{V_D}{nV_T}} - 1\right)$

For BJTs:

	Active	Saturation	Cut-off
	BE forward biased BC reverse biased	BE forward biased BC forward biased	BE reverse biased BC reverse biased
npn	$I_C = \beta\, I_B = \alpha\, I_E\,, V_{BE} \approx 0.7V$	$I_B > \frac{I_C}{\beta}\,, V_{CE} \approx 0.2V$	$I_B \approx I_C \approx I_E \approx 0$
pnp	$I_C = \beta\, I_B = \alpha\, I_E\,, V_{EB} \approx 0.7V$	$I_B > \frac{I_C}{\beta}, V_{EC} \approx 0.2V$	$I_B \approx I_C \approx I_E \approx 0$

$$I_C(\text{active}) = I_S\, e^{\frac{|V_{BE}|}{V_T}}\left(1 + \frac{|V_{CE}|}{V_A}\right) \qquad \alpha = \frac{\beta}{\beta+1} \qquad V_T = 25mV$$

$$g_m = \frac{1}{r_m} = \frac{I_C}{V_T} \qquad r_\pi = \beta\, r_m = \frac{\beta}{g_m} \qquad r_o = \frac{V_A}{I_C}$$



For MOSFETs:

	Saturation	Triode	Cut-off
NFET (V_{TH}>0)	$V_{GS} > V_{TH}$ & $V_{GD} < V_{TH}$	$V_{GS} > V_{TH}$ & $V_{GD} > V_{TH}$	$V_{GS} < V_{TH}$ & $V_{GD} < V_{TH}$
PFET (V_{TH}<0)	$V_{GS} < V_{TH}$ & $V_{GD} > V_{TH}$	$V_{GS} < V_{TH}$ & $V_{GD} < V_{TH}$	$V_{GS} > V_{TH}$ & $V_{GD} > V_{TH}$

$$I_D(saturation) = \frac{K'}{2}\,(V_{GS} - V_{TH})^2\,(1 + \lambda V_{DS})$$

$K' \equiv K_n = \mu_n C_{ox} {W}/{L}$ for NFETS

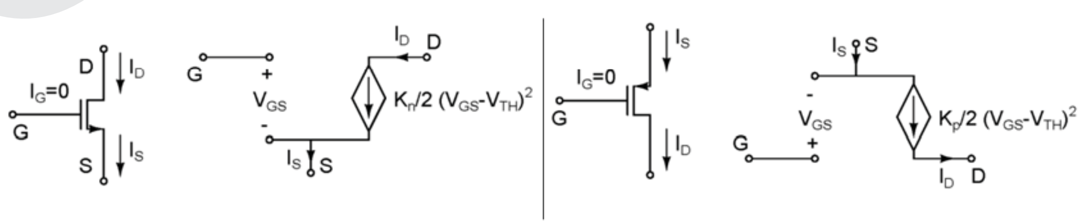
$K' \equiv K_p = \mu_p C_{ox} {W}/{L}$ for PFETS

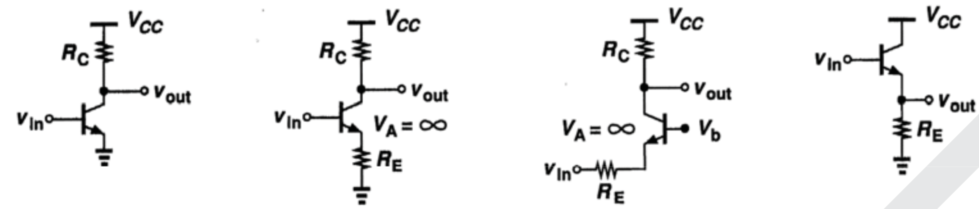
$$I_D(triode\,) = \frac{K'}{2}\,[2(V_{GS} - V_{TH})V_{DS} - V_{DS}^2]$$

$$r_{DS}(deep\ triode) \approx \frac{1}{K'(V_{GS} - V_{TH})}$$

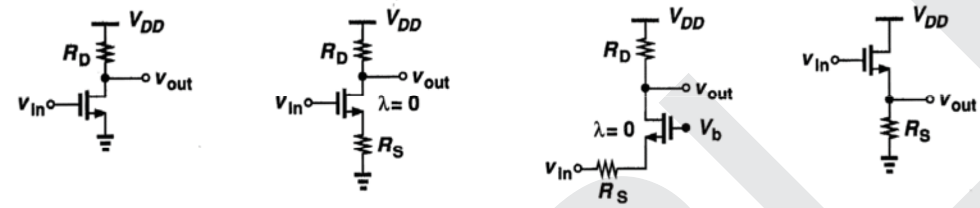
$$g_m = K'(V_{GS} - V_{TH}) = \sqrt{2\,K' I_D} = \frac{2I_D}{V_{GS} - V_{TH}}$$

$$r_o = \frac{1}{\lambda I_D}$$

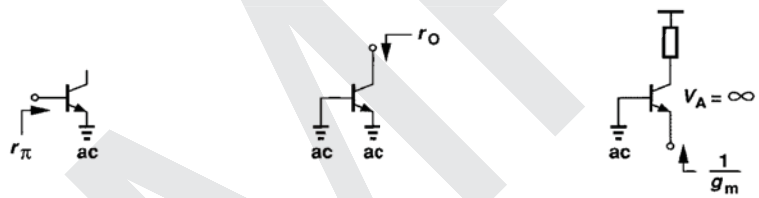


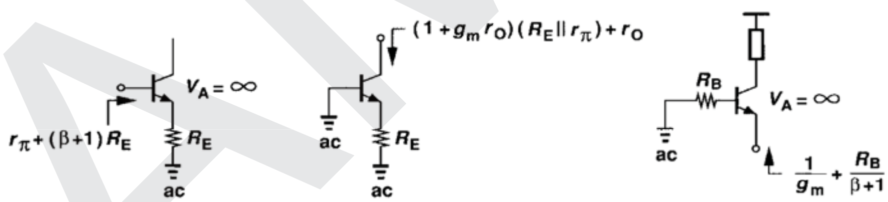


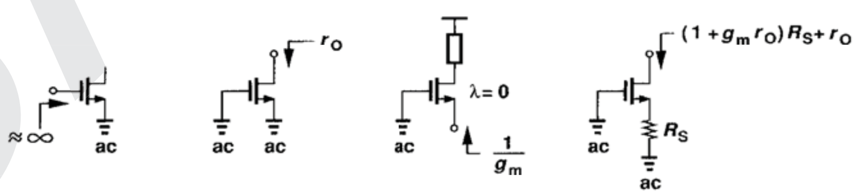
$A_v = -g_m(R_C \| r_O)$ $A_v = -\dfrac{R_C}{\frac{1}{g_m}+R_E}$ $A_v = \dfrac{R_C}{\frac{1}{g_m}+R_E}$ $A_v = \dfrac{R_E \| r_O}{\frac{1}{g_m}+R_E \| r_O}$

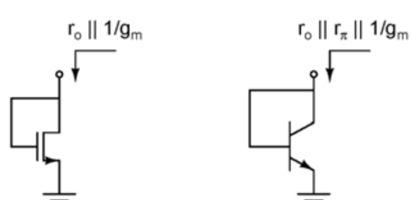


$A_v = -g_m(R_D \| r_O)$ $A_v = -\dfrac{R_D}{\frac{1}{g_m}+R_S}$ $A_v = \dfrac{R_D}{\frac{1}{g_m}+R_S}$ $A_v = \dfrac{R_S \| r_O}{\frac{1}{g_m}+R_S \| r_O}$



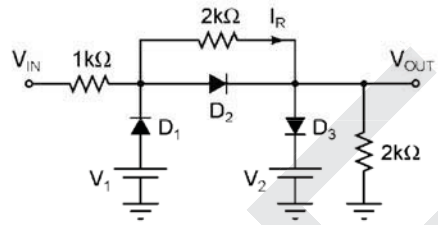






<u>Question</u> 1 [10 marks]

Consider the diode circuit to the right where the diodes are **ideal**, $V_1 = -5V$, and $V_2 = +2V$. The input voltage is slowly increased from $-10V$ to $+10V$.

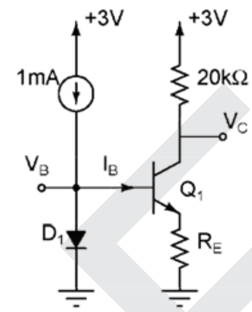


1.a. [5 marks] What is the range for I_R?

__________ $< I_R <$ __________

1.b. [5 marks] Diode D_1 turns off as the input voltage is increased from $-10V$. What is the minimum input voltage that switches diode D_1 off?

Question 2 [15 marks]



Consider the circuit to the right where the base current of Q_1 can be ignored (i.e., $I_B \approx 0$ or $\beta \rightarrow \infty$). For both the transistor and the diode, assume $V_T = 25mV$, $I_S = 10^{-15}A$, and $V_A = \infty$. Provide the answers with three significant digits.

2.a. [5 marks] What is V_B?

$V_B =$ _______V

2.b. [7 marks] If $R_E = 1k\Omega$, what is the collector current of Q_1 (Hint: use iterations)?

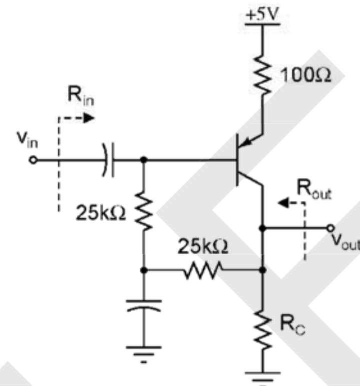
$I_C =$ _______mA

2.c. [3 marks] What is V_C for the collector current calculated in the above?

$V_C =$ _______V

Question 3 [20 marks]

Consider the circuit shown to the right where the capacitors are assumed to be AC short circuits. Assume $\beta = 100$, $V_T = 25mV$, $V_{EB}(on) = 0.6V$, $V_{EC}(sat) = 0.2V$, and $|V_A| = \infty$.



3.a. [4 marks] If $R_C = 10k\Omega$, what is the collector current of the transistor? Verify the operating region of the transistor.

$I_C =$ _______mA Operating region: __________

3.b. [4 marks] Calculate the small signal parameters and draw the small signal equivalent circuit.

$g_m =$ __________mS $r_\pi =$ ___________$k\Omega$

3.c. [4 marks] What is the voltage gain of the circuit?

$A_v = \frac{v_{out}}{v_{in}} =$ ____________ V/V

3.d. [4 marks] What is the input resistance of the circuit?

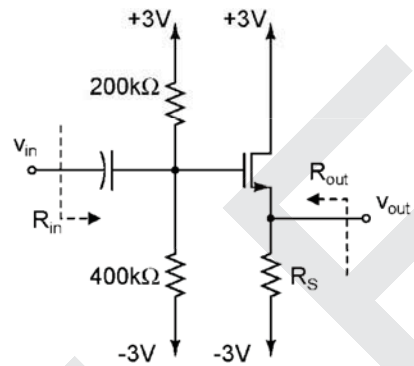
$R_{in} =$ ____________ $k\Omega$

3.e. [4 marks] What is the output resistance of the circuit?

$R_{out} =$ ____________ $k\Omega$

Question 4 [20 marks]

Consider the circuit shown to the right where the capacitor is AC short circuit. Assume $R_S = 15k\Omega$, $V_{TH} = 2V$, $K_n = 1mA/V^2$, and $\lambda = 0$.



4.a. [6 marks] What is the drain current of the transistor? Verify the operating region of the transistor.

$I_D =$ ________mA

Operating region: __________

4.b. [3 marks] Calculate g_m and draw the small signal equivalent circuit.

$g_m =$ __________mS

4.c. [4 marks] What is the voltage gain of the circuit?

$A_v = \frac{v_{out}}{v_{in}} =$ ______________ V/V

4.d. [3 marks] What is the input resistance of the circuit?

$R_{in} =$ ______________ $k\Omega$

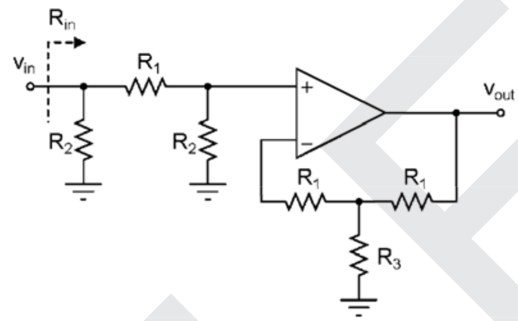
4.e. [4 marks] What is the output resistance of the circuit?

$R_{out} =$ ______________ $k\Omega$

Question 5 [20 marks]

The OpAmps are ideal in circuits shown below.

5.a. [5 marks] What is the input resistance of the circuit as a function of resistor values?



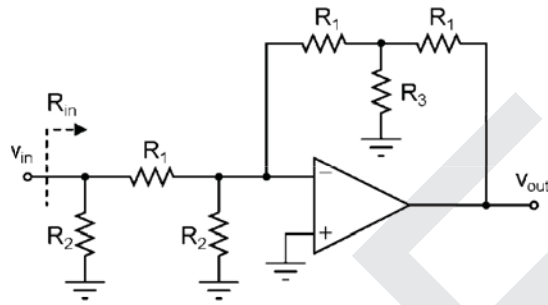
R_{in} = ______________________

5.b. [5 marks] What is the voltage gain of the circuit assuming $R_1 = 2k\Omega$, $R_2 = 10k\Omega$, and $R_3 = 100\Omega$?

$A_v = \frac{v_{out}}{v_{in}} =$ __________*V/V*

5.c. [4 marks] What is the input resistance of the circuit as a function of resistor values?

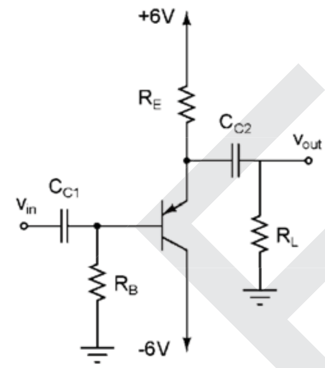
R_{in} = ____________________



5.d. [6 marks] What is the voltage gain of the circuit assuming $R_1 = 2k\Omega$, $R_2 = 10k\Omega$, and $R_3 = 100\Omega$?

$A_v = \frac{v_{out}}{v_{in}} =$ __________V/V

Question 6 [10 marks]



Shown to the right is a common-collector circuit similar to what you studied in Lab 3.

6.a. [4 marks] We monitor the output signal while applying a signal with a constant amplitude to the input of the circuit. We notice that the amplifier gain at 1kHz is smaller than the gain at 100kHz. The gain remains relatively constant for frequencies higher than 100kHz. Explain what may be the most possible reason for this observation.

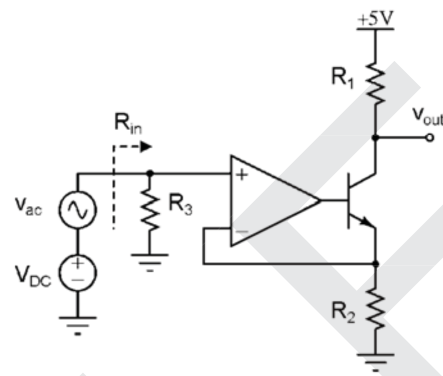
6.b. [6 marks] We measure the gain of the amplifier at 1MHz with $R_L = 100\Omega$ to be 0.9V/V. When we change the load resistance to $R_L = 200\Omega$, the gain increases to 0.95V/V. What is the output resistance of the circuit? (Hint: you do not need device parameters or component values.)

<u>Question 7</u> [15 marks]

The OpAmp is ideal in circuit shown to the right.

The transistor parameters are $\beta = 100$, $V_T = 25mV$, $V_{BE}(on) = 0.6V$, and $V_{CE}(sat) = 0.2V$. Assume $R_1 = 35k\Omega$, $R_2 = 1k\Omega$, and $R_3 = 1M\Omega$.

V_{DC} is a $100mV$ DC voltage source and v_{ac} is a small signal AC voltage source.



7.a. [4 marks] What are the DC collector current and voltage of the transistor?

$I_C =$ ________mA $V_C =$ ________V

7.b. [7 marks] What is the small signal voltage gain of the circuit?

$A_v = \frac{v_{out}}{v_{ac}} =$ ___________V/V

7.c. [4 marks] What is the input resistance of the circuit?

$R_{in} =$ _______________

You may use this space to answer any of the questions with proper reference to the question.