University of California at Berkeley
College of Engineering
Dept. of Electrical Engineering and Computer Sciences

EE 105 Midterm II

Fall 2001 | Prof. Roger T. Howe | November 14, 2001

________________,________________
Your Name (Last, First)

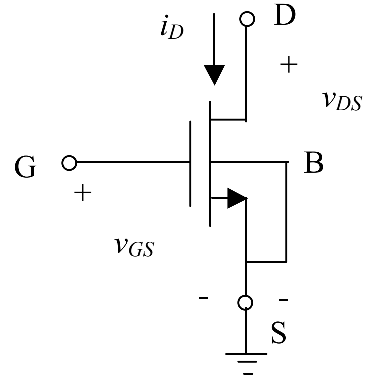
Guidelines

Closed book and notes; one 8.5” x 11” page (both sides) of *your own notes* is allowed.
You may use a calculator.
Do not unstaple the exam.
Show all your work and reasoning on the exam in order to receive full or partial credit.

Score

Problem	Points Possible	Score
1	16	
2	24	
3	10	
Total	50	

1. Short-Channel MOSFET Model [17 points].



Device parameters:

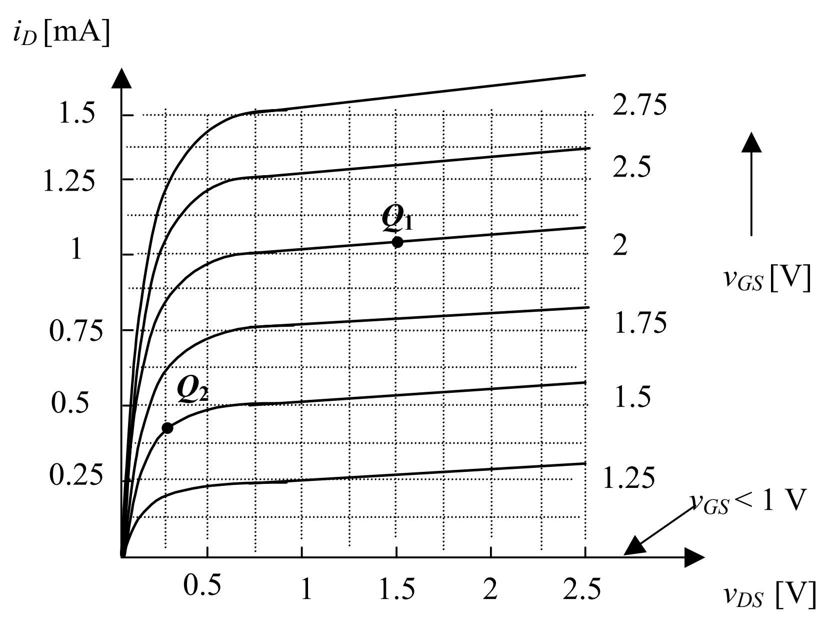
C_{ox} = 4 fF/ μm²
W = 5 μm
L = 0.1 μm
V_{Tn} = 1 V
$V_{DS,sat}$ = 0.75 V
λ_n = 0.05 V^{-1}
v_{sat} = 10^7 cm/s

An improved model for the velocity-saturated MOSFET is:

$$i_D = C_{ox} W v_{sat} (v_{GS} - V_{Tn}) \left(\frac{v_{DS}}{V_{DS,sat}} \right) \left(1 - \frac{v_{DS}}{2V_{DS,sat}} \right) \text{ when } v_{DS} \le V_{DS,sat} = 0.75\text{ V (triode region)}$$

$$i_D = \left(\frac{1}{2} \right) C_{ox} W v_{sat} (v_{GS} - V_{Tn}) \left[\frac{1 + \lambda_n v_{DS}}{1 + \lambda_n V_{DS,sat}} \right] \text{ when } v_{DS} > V_{DS,sat} = 0.75\text{ V (saturation region)}$$

The drain characteristics for this short-channel MOSFET model are:



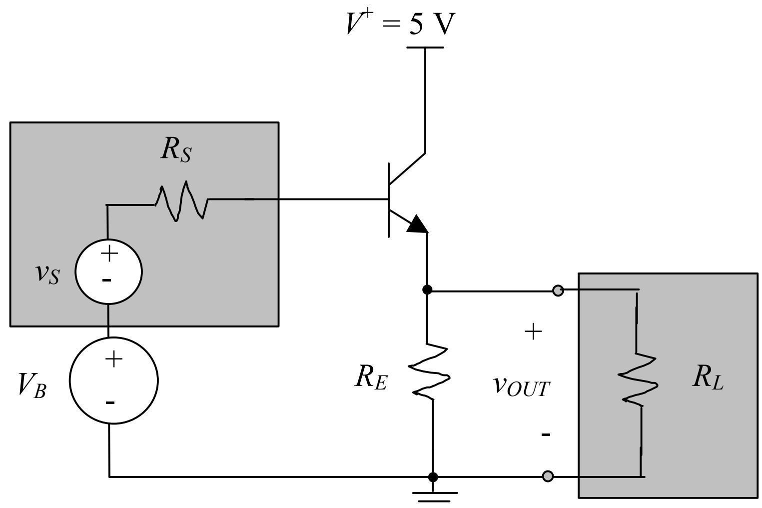
(a) [4 pts.] What is the small-signal transconductance g_m at the operating point Q_1 in mS? You can find the answer either from the drain current equations or graphically: in either case, be sure to explain your method clearly.

(b) [4 pts] What is the small-signal drain resistance r_o at the operating point Q_1 in kΩ? For this parameter at this operating point, graphical techniques don't give a sufficiently accurate answer.

(c) [4 pts.] What is the transconductance g_m at the operating point Q_2 in mS? You can find the answer either from the drain current equations or graphically: in either case, be sure to explain your method clearly.

(d) [4 pts] What is the small-signal drain resistance r_o at the operating point Q_2 in kΩ? You can find the answer either from the drain current equations or graphically: in either case, be sure to explain your method clearly.

2. BJT voltage buffer [18 pts.]



Given:
$\beta_o = 100$
$V_{th} = 25$ mV
$V_A = 50$ V

$R_S = 5$ kΩ
$R_E = 5$ kΩ
$R_L = 2.5$ kΩ

(a) [3 pts.] Find the numerical value of V_B such that $V_{OUT} = 2.5$ V. Your answer should be accurate to +/- 5%. Notes: (i) the gray boxes indicate small-signal elements that can be neglected for the DC bias analysis and (ii) the DC base current I_B of the bipolar transistor can be neglected for the bias solution.

(b) [3 pts.] What is the numerical value of the DC collector current I_C for this amplifier?

(c) [4 pts.] Find the numerical value of the input resistance R_{in} of this amplifier in kΩ.

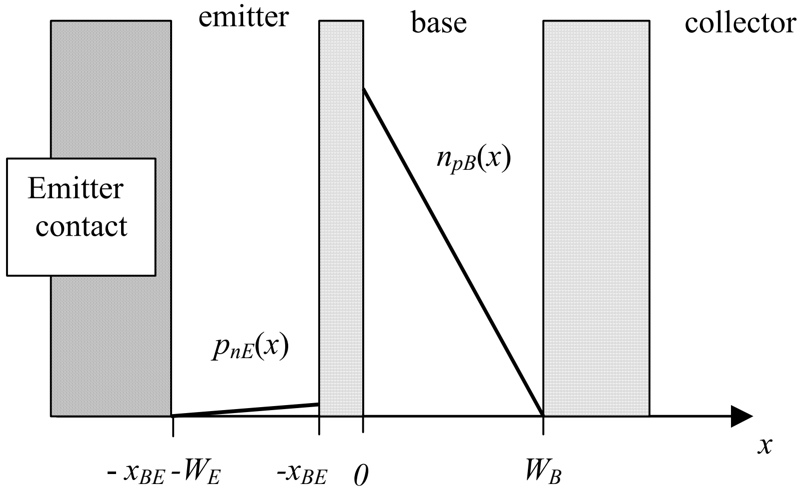
(d) [4 pts.] Find the numerical value of the output resistance R_{out} in kΩ.

(e) [3 pts.] Find the numerical value two-port parameter A_v, the open-circuit voltage gain, for this amplifier.

(f) [4 pts.] Find the overall voltage gain v_{out} / v_s with R_S and R_L present (values of which are given next to the schematic on the previous page). If you couldn't solve (a), (b), or (c), you can assume that R_{in} = 7 kΩ, R_{out} = 5 kΩ, and A_v = 0.8. Needless to say, these are not correct answers to (a), (b), or (c).

(g) [3 pts.] Suppose that the input voltage $v_s(t) = \hat{v}_s \cos(\omega t)$. What is the maximum amplitude $\hat{v}_s$ for which the small-signal, two-port model you've derived in parts (b)-(c) is reasonably accurate? You can assume that the frequency of $v_s(t)$ is low enough that capacitors can be neglected. Justify your answer.

3. npn bipolar transistor device physics [10 pts.]



Given:
Base width = W_B = 100 nm = 0.1 μm
Emitter-base junction area = A_E = 25 μm^2
Emitter width = W_E = 70 nm = 0.07 μm
Base-collector junction area = A_C = 50 μm^2
Electron diffusion constant in base: D_n = 20 cm^2/s
Hole diffusion constant in emitter: D_p = 5 cm^2/s
Electron charge: q = -1.6 x 10^{-19} C
Intrinsic concentration: n_i = 10^{10} cm^{-3}

(a) [4 pts.] The collector current for this forward-active npn bipolar transistor is I_C = 20 μA. From the cross section of the device shown above, find the numerical value of the minority electron concentration at x = 0, at the base side of the emitter-base depletion region.

(b) [3 pts.] For the bias conditions in part (a), the base-emitter voltage V_{BE} = 692.5 mV. What is the doping concentration N_A in the base? If you couldn't solve part (a), you can use $n_{pB}(0) = 8 \times 10^{14}$ cm^{-3}, which is not the correct answer to part (a), of course.

(c) [3 pts.] The minority hole concentration in the emitter at the edge of the emitter-base depletion region is (0.05)*(your answer to part (a)). What is the forward-active DC current gain β_F for this transistor? Note that you don't need to have answered part (a) in order to answer this part!