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

EE 105 Midterm II

Spring 2002 Prof. Roger T. Howe April 17, 2002

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Your Name (Last, First)

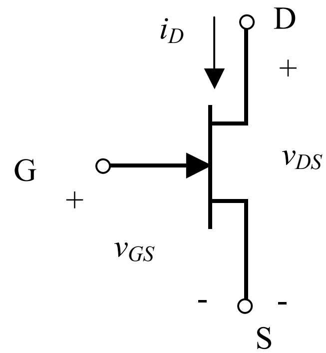
Guidelines

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	18	
3	16	
Total	50	

1. Junction Field-Effect Transistor (JFET) Model. [16 points].



Device parameters:

$I_{DSS} = 125\ \mu A$
$V_P = -1.5$ V
$\lambda_n = 0.05\ V^{-1}$

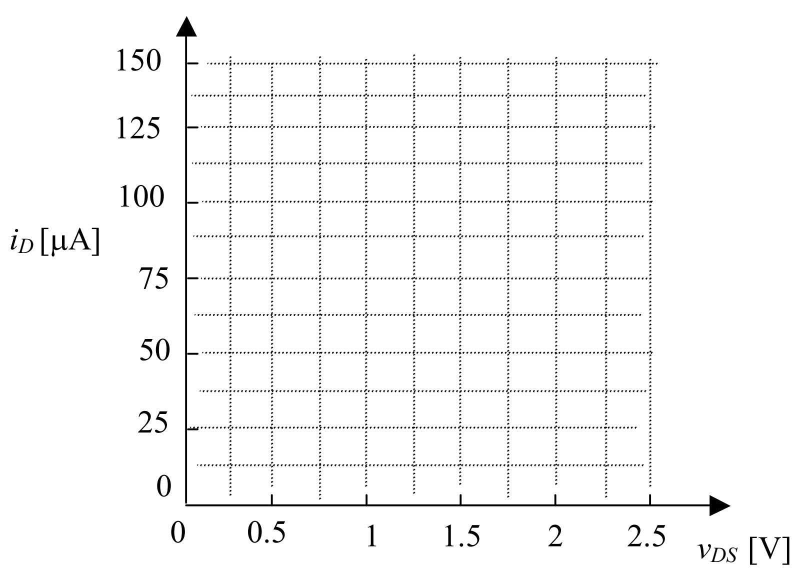
A simplified large-signal model for an n-channel JFET is:

$$i_D = \frac{2I_{DSS}}{V_P^2}(v_{GS} - V_P - \frac{v_{DS}}{2})v_{DS}(1 + \lambda_n v_{DS}) \text{ for } v_{DS} \le v_{GS} - V_P \text{ and } V_P \le v_{GS} \le 0 \text{ V (triode)}$$

$$i_{D.SAT} = \frac{I_{DSS}}{V_P^2}(v_{GS} - V_P)^2(1 + \lambda_n v_{DS}) \text{for } v_{DS} \ge v_{GS} - V_P \text{ and } V_P \le v_{GS} \le 0 \text{ V (saturation)}$$

where V_P is the pinch-off voltage and λ_n is the "fudge factor."

(a) [4 pts.] Sketch the drain characteristics for this JFET on the graph below for V_{GS} = 0 V, -0.5 V, -1 V, and –1.5 V. You can set λ_n= 0 for this part. Your current values in saturation should be accurate; the triode curves can be sketched.

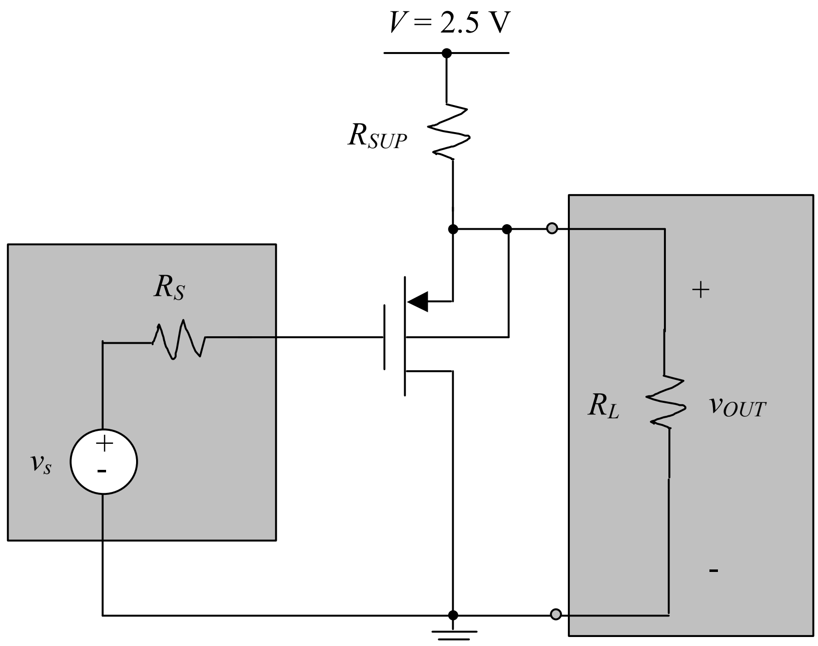


(b) [4 pts.] What is the numerical value of the small-signal transconductance g_m at the operating point Q_1 (V_{GS} = -0.5 V, V_{DS} = 1.5 V)? Notes: (i) λ_n is not zero for this part, (ii) you don't need the plots in part (a) in order to answer this question.

(c) [4 pts.] What is the numerical value of the small-signal drain resistance r_o at the operating point Q_1 (V_{GS} = -0.5 V, V_{DS} = 1.5 V). Notes: (i) λ_n is not zero for this part, (ii) you don't need the plots in part (a) in order to answer this question.

(d) [4 pts.] What is the numerical value of the small-signal transconductance g_m at the operating point Q_2 (V_{GS} = -0.5 V, V_{DS} = 0.5 V). Again, you don't need the plot in part (a) in order to answer this question.

2. MOSFET single stage amplifier [18 pts.]



Given:
$L = 1\ \mu m$
$\mu_p C_{ox} = 62.5\ \mu A/V^2$
$V_{Tp} = -1\ V$
$\lambda_p = 0.025\ V^{-1}$
$g_{mb} = g_m/10$

$R_S = 10\ k\Omega$
$R_{SUP} = 5\ k\Omega$
$R_L = 1\ k\Omega$

(a) [3 pts.] Find the numerical value of channel width W in μm in order that the DC output voltage $V_{OUT} = 1.25$ V. *Note*: the gray boxes indicate small-signal elements that can be neglected for the DC bias analysis.

(b) [3 pts.] What is DC power dissipated in the MOSFET in μW?

(c) [3 pts.] Find the numerical value of the output resistance R_{out} of this amplifier in kΩ. If you couldn't solve part (a), you can assume for this part that the channel width $W = 100$ μm (not the correct answer to (a), of course.)

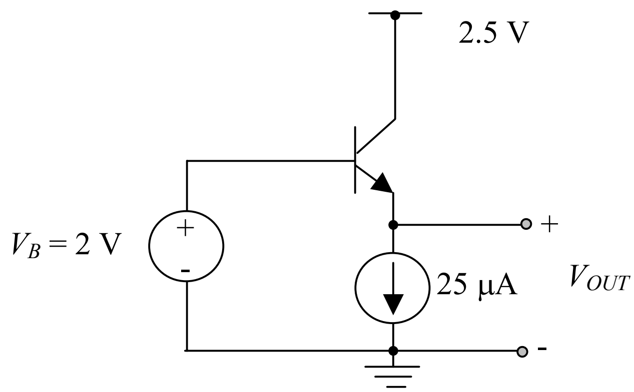
(d) [3 pts.] Find the numerical value of the two-port parameter A_v, the open-circuit voltage gain, for this amplifier. Again, if you couldn't solve part (a), you can assume for this part that the channel width $W = 100$ μm (not the correct answer to (a), of course.)

(e) [3 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 (c) or (d), you can assume for this part that $R_{out} = 2.5$ kΩ, and $A_v = 0.85$. Needless to say, these are not correct answers to either (c) or (d).

(f) [3 pts.] We now remove the small-signal source and its resistance and replace it with a large-signal source v_{IN}; we also remove the load resistor. Assuming the MOSFET remains in the saturation (constant-current) region and neglecting channel-length modulation ($\lambda_n = 0$), find an equation for v_{IN} in terms of v_{OUT}. If you couldn't solve part (a), you can assume that $W = 100\ \mu\text{m}$ for this part.

What is the numerical value of v_{IN} for the case when $v_{OUT} = 2$ V?

3. npn bipolar transistors [16 pts.]



Given: Base width = W_B = 100 nm = 0.1 µm Emitter-base junction area = A_E = 5 µm^2 Emitter width = W_E = 75 nm = 0.075 µm Base-collector junction area = A_C = 15 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} V_{th} = 26 mV

(a) [4 pts.] Find the numerical value of the electron diffusion current density J_{nB} in the base [units µA/µm^2]. Neglect the base current I_B for this part.

(b) [4 pts.] What is the numerical value of $n_{pB}(x = 0)$, the minority electron concentration in the base at the edge of the emitter-base depletion region? Again, you can neglect the base current I_B for this part.

(c) [3 pts.] Find the numerical value of V_{OUT} to 3 significant figures. The base doping is $N_{aB} = 1 \times 10^{17}$ cm^{-3}. You can neglect the base current for this part, too.

(d) [4 pts.] We now increase V_B above 2 V to the point where the minority carrier concentrations in the bipolar transistor are given by the plot below. The value of $n_{pB}(0)$ is unchanged from parts (b) and (c). What is the value of V_B to 3 significant figures? *Note*: if you can't find the exact value, the answer to 2 significant figures is worth 2 pts.