Final Exam (200 pts) - Fall 2007 - M. Cahay

Name:

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ELECTRONICS I

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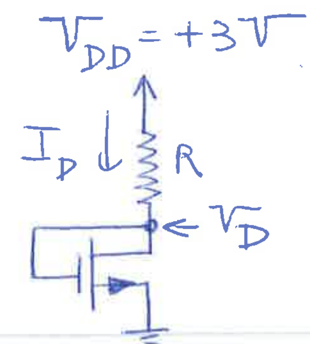
1. (25 pts) Design the circuit below to obtain a current I_D of 80 μA. Find the value of the resistor R and the value of the drain voltage. For this NMOS transistor, use $V_t = 0.6V$, $\mu_n C_{ox} = 200\ \mu A/V^2$, L = 0.8$\mu m$ and W = 4 μm. Neglect the short-channel effect, i.e., assume $\lambda = 0$.



$V_{DG} = 0 \rightarrow V_D = V_G \rightarrow$ FET is operating in the saturation regime.

$I_D = \frac{1}{2} \mu_n C_{ox} \frac{W}{L} (V_{GS} - V_t)^2$ (+5)

$\rightarrow V_{GS} - V_t = \sqrt{\frac{2 I_D}{\mu_n C_{ox} (W/L)}} = 0.4V$ (+5)

$V_{GS} = V_t + (V_{GS} - V_t) = 0.6 + 0.4 = 1V$ (+5)

$\rightarrow V_D = V_G = +1$ (+5)

$\rightarrow R = (V_{DD} - V_D)/I_D = \frac{3-1}{0.080} = 25\,k\Omega$ (+5)

2. (25 pts) A particular enhancement MOSFET has a V_t of 1 V and $k_n{}'(\frac{W}{L}) = 0.1 mA/V^2$ and $\lambda = 0$. It is to be operated in the saturation regime.

- To be operated with $I_D = 0.2mA$, find the required V_GS and the minimum required V_{DS}.
- Repeat the previous question with $I_D = 0.8mA$.

(a) $i_D = \frac{k_n'}{2} \frac{W}{L} (V_{GS} - V_t)^2$ (+3)

$0.2 \cdot 10^{-3} = \frac{1}{2} \, 0.1 \cdot 10^{-3} (V_{GS} - 1)^2$

→ $V_{GS} - 1 = 2 \Rightarrow V_{GS} = 3V$ (+4)

$V_{DS\,min} = V_{GS} - V_t = 3 - 1 = 2V$ (+3) (+2.5)

12.5

(b) $i_D = 0.8 \, mA$

→ $0.8 = \frac{1}{2} \, 0.1 (V_{GS} - 1)^2$ (+3)

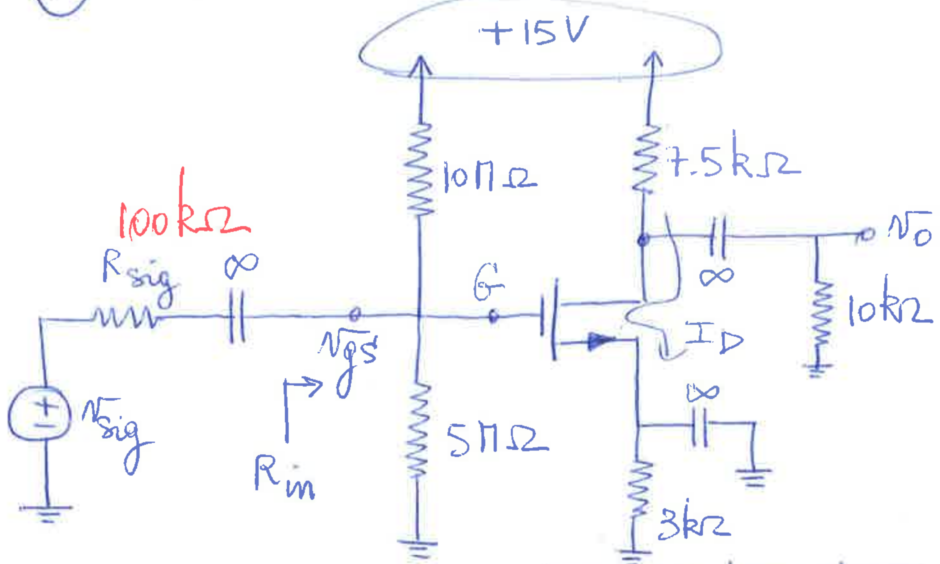
$V_{GS} - 1 = 4 \Rightarrow V_{GS} = 5V$ (+4)

$V_{DS\,min} = V_{GS} - V_t = 5 - 1 = 4V$ (+2.5) (+3)

12.5

4. (30 pts) In the circuit amplifier below, the signal source is coupled to the gate through a very large capacitor (i.e, which behaves as a short at the frequency of operation of the signal source). The output voltage is coupled to the load via a coupling capacitor which also behaves as a short at the frequency of operation of the amplifier.

- (+2) (a) Is the amplifier circuit, (a) a common source, (b) a common gate, or (c) a common drain configuration?
- (b) If the transistor has a $V_t = 1$ V and $k_n'(\frac{W}{L}) = 2.0mA/V^2$, check that the biasing configuration with the four resistors establish a drain current of 1 mA, a V_{GS} value of 2 V, and a drain voltage value of 7.5 V. Assume $\lambda = 0$.
- (c) Using the previous results, calculate the transconductance g_m in mS and the value of r_0. The latter will be included in the small AC circuit model to be analyze next. Use $V_A = 100V$.
- (d) Draw the complete small signal equivalent circuit for the amplifier. (Use hybrid-π model) include effects of r_0.
- (e) Calculate the input resistance of that amplifier.
- (f) Calculate v_{gs}/v_{sig}.
- (g) Calculate v_0/v_{gs}.
- (h) Finally, calculate v_0/v_{sig}.



[In saturation]

(b) $V_G = \left(\frac{5}{15}\right)15 = 5V$ (+1)

$I_D = \left(\frac{k_n'}{2}\right)\frac{W}{L}(V_{GS} - V_t)^2$

$I_D = \frac{2}{2}(2-1)^2 = 1mA$ ✓ (+2)

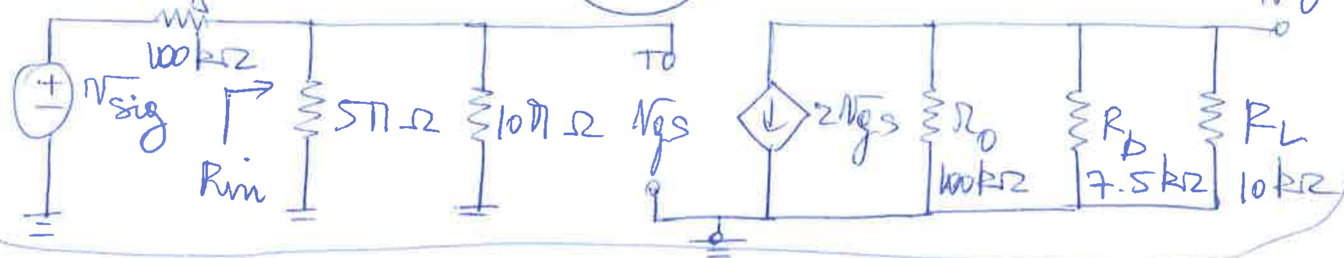
$V_D = 15 - 7.5k\Omega(1mA) = 7.5V$ ✓ (+2)

(c) $g_m = k_n'\frac{W}{L}(V_{GS} - V_t)$ (+1)

$= 2\frac{mA}{V^2}(2-1) = 2mS$; $r_0 = \frac{V_A}{I_D} = \frac{100}{1mA} = 100k\Omega$ (+1)

(d)

+10



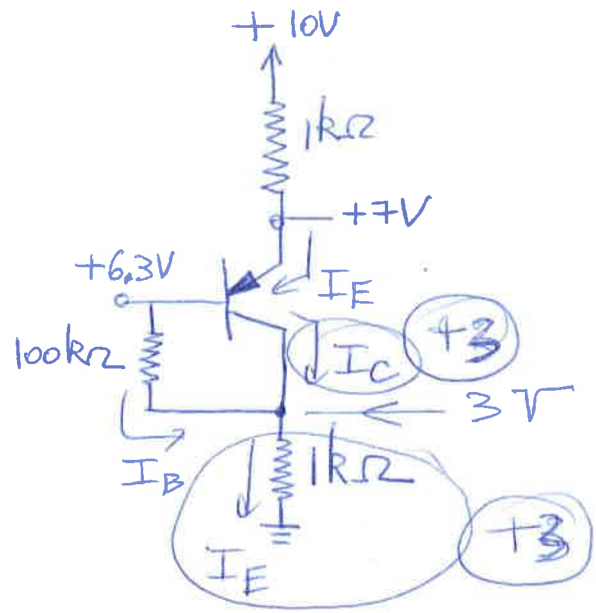
(e) $R_{in} = (5M\Omega // 10M\Omega) = 3.33\,M\Omega$ (+3)

(f) $\frac{v_{gs}}{v_{sig}} = \frac{R_{in}}{R_{sig}+R_{in}} = \frac{3.33}{0.1+3.33} = 0.97\ V/V.$ (+3)

(g) $\frac{v_o}{v_{gs}} = -2(r_o // R_D // R_L) = -2\,mS(4.1k\Omega) = -8.2\ V/V$ (+3)

$\frac{v_o}{v_{sig}} = -7.95\ V/V$ (+2)

5. (20 pts) Measurements on the circuit below produce the values of the labeled voltages as indicated. Find the corresponding value of β for that transistor.



$$I_E = \frac{10-7}{1k\Omega} = 3\ mA$$ (+4)

$$I_B = \frac{6.3-3}{100k\Omega} = \frac{3.3}{100}\ mA = 33\ \mu A.$$ (+4)

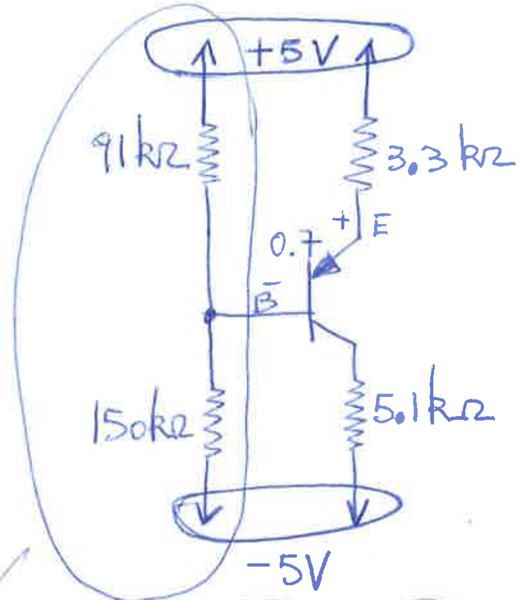
$$I_C + I_B = I_E$$ (+2)

$$I_E = (\beta+1) I_B \Rightarrow \quad \beta+1 = \frac{I_E}{I_B}$$

$$\beta = \frac{I_E}{I_B} - 1 = \frac{3\ 10^{-3}}{33\ 10^{-6}} - 1$$ (+2)

$$\beta = \frac{10^3}{11} - 1 \simeq 90$$ (+2)

6. (20 pts) For the circuit shown below, find the value of the emitter current using the "loop equation". Hint: first replace the two leftmost resistors by their Thevenin equivalent. Remember "no rabbit out of the hat!". You must show how you derive the loop equation. Assume $V_{EB} = 0.7V$ and $\beta = 100$.



$I_B = \frac{I_E}{\beta+1}$

$\beta = 100$

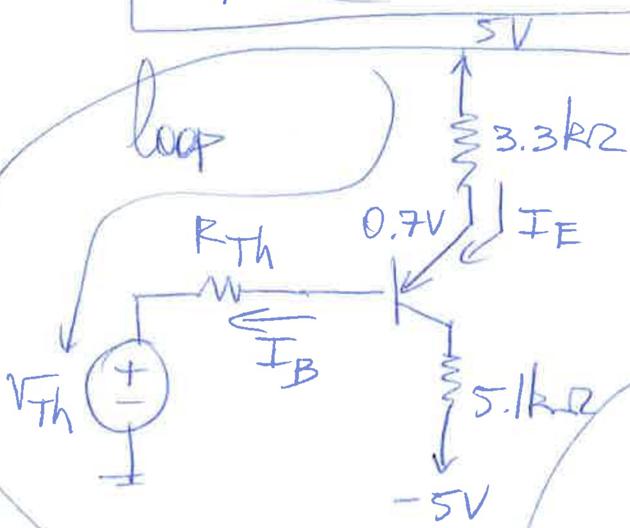
(+3) (+3) (+1)

$V_{Th} = \left(\frac{150}{91+150}\right) 10V - 5V = 1.22V$

(+3)

$R_{Th} = (91 // 150)\,k\Omega = 56.63\ k\Omega$

in mA



(+9)

$5 - 3.3 I_E - 0.7 - R_{Th} \frac{I_E}{\beta+1} = V_{Th}$

$\rightarrow I_E = \frac{5 - 0.7 - V_{Th}}{3.3 + \frac{R_{Th}}{\beta+1}} = \frac{3.08}{3.86}$

$\rightarrow I_E = 0.798$ mA

(+1)