Name: ____________________ College Number: ____________________

EEE210B: Electronic Devices and Circuits Friday, 14 March 2014

Fourth Quiz

REMARKS:

1. Hand held non-communicating calculator is allowed,
2. Closed book quiz,
3. Formulae sheets are attached,
4. Marks distribution:
   Question #1: 1 points
   Question #2: 3 points
   Question #3: 3 points
   Question #4: 3 points
5. Justify all your answers.

# 1	
# 2	
# 3	
# 4	

The MOSFETs in the circuit of figure 1 is biased in the active region at the Q-point (you need not verify this)

$$(V_{GS} = 2.64 \text{ V}, I_D = 0.913 \text{ mA}, V_{DS} = 5.22 \text{ V}).$$

Its parameters are $K = 50\text{mA/V}^2$ and $V_t = 2.5$ V. Assume the capacitors are *very large*.

1. Sketch the AC model of the circuit in its simplified form.
2. Calculate the voltage gain, the input impedance, the output impedance, the current gain and the power gain (I would recommend that you calculate them in this order but you don't need to).
3. Calculate the expressions of $I_D(t)$ and $V_{DS}(t)$ as functions of $v_{in}(t)$.
4. Calculate the AC load line, sketch it on the static characteristic of the MOSFET in figure 2 and calculate the allowable range of $v_{in}(t)$ for which the MOSFET remains in the active region.

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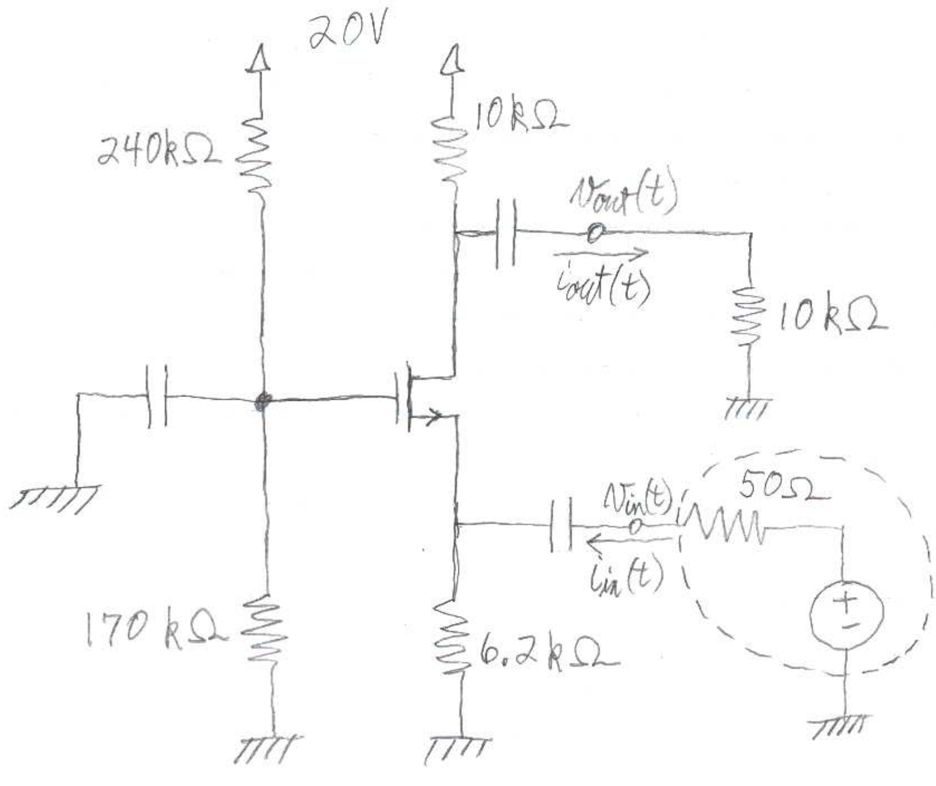

Figure 1:

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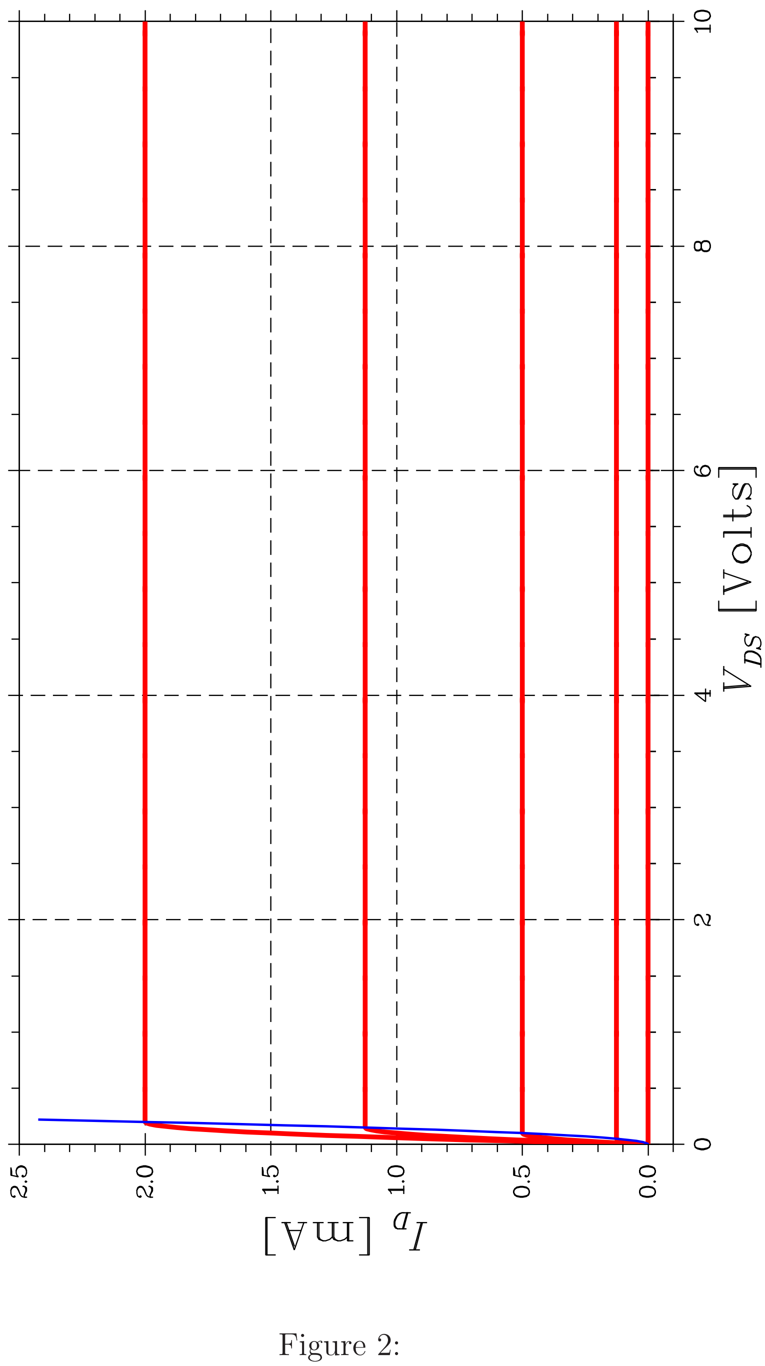

Figure 2:

END

Formula Sheets

$\cos\theta = \sin(\theta + 90°)$

$2\cos u \cos v = \cos(u - v) + \cos(u + v)$

$2\sin u \sin v = \cos(u - v) - \cos(u + v)$

$2\sin u \cos v = \sin(u - v) + \sin(u + v)$

$2\sin\theta\cos\theta = \sin(2\theta)$

$2\cos^2\theta = 1 + \cos(2\theta)$

$2\sin^2\theta = 1 - \cos(2\theta)$

$\cos\theta = \frac{e^{j\theta} + e^{-j\theta}}{2}$

$\sin\theta = \frac{e^{j\theta} - e^{-j\theta}}{2j}$

$\frac{\omega}{2\pi}\int_{2\pi/\omega}\left(A\cos(\omega t + \phi)\right)^2 dt = \frac{A^2}{2}$

$T = \frac{1}{f} = \frac{2\pi}{\omega}$

$P = \frac{V^2}{R} = RI^2$

$v = Ri$

$i = C\frac{dv}{dt} \leftrightarrow v = \frac{1}{C}\int i\,dt$

$v = L\frac{di}{dt} \leftrightarrow i = \frac{1}{L}\int v\,dt$

$\mathbf{Z}_R = R$

$\mathbf{Z}_C = \frac{-j}{\omega C}$

$\mathbf{Z}_L = j\omega L$

$x_1 \| x_2 \| \ldots \| x_n = \left(\sum_{i=1}^{n} \frac{1}{x_i}\right)^{-1}$

$R_{eq} = (R_1 || R_2) \;\Rightarrow\; R_1 = \left(R_{eq} || (-R_2)\right)$

$v_{R_1}(t) = v(t)\frac{R_1}{R_1 + R_2}$

$i_{R_1}(t) = i(t)\frac{R_2}{R_1 + R_2}$

$q = C\,v$

$K_1 + K_2\, e^{-t/\tau}$

$$\tau = \begin{cases} R_{eq}C_{eq} \\ L_{eq}/R_{eq} \end{cases}$$

$I = I_s\left(e^{V/nV_T} - 1\right)$

$V_T = \frac{kT}{q}$

$k = 1.38 \times 10^{-23}$ joules/Kelvin

$q = 1.602 \times 10^{-19}$ Coulomb

$V_T \approx 25.2$ mV at 20 °C

$$n \approx \begin{cases} 1 & \text{for Germanium} \\ 2 & \text{for Silicon} \end{cases}$$

$V_{GS} < V_P$

$$\begin{array}{c} V_P < V_{GS} < 0 \\ V_{DS} > V_{GS} - V_P \end{array}$$

$$\begin{array}{c} V_P < V_{GS} < 0 \\ V_{DS} < V_{GS} - V_P \end{array}$$

$I_D = I_{DSS}\left(2\left(\frac{V_{GS}}{V_P} - 1\right)\left(\frac{V_{DS}}{V_P}\right) - \left(\frac{V_{DS}}{V_P}\right)^2\right)$

$I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2$

$g_m = \frac{2I_{DSS}}{-V_P}\left(1 - \frac{V_{GS}}{V_P}\right)$

$V_{GS} < V_t$

Formulae Sheets (continued)

$$V_{GS} > V_t \qquad V_{DS} > V_{GS} - V_t$$

$$V_{GS} > V_t \qquad 0 < V_{DS} < V_{GS} - V_t$$

$I_D = K\Big(2\big(V_{GS} - V_t\big)V_{DS} - V_{DS}^2\Big)$

$I_D = K\big(V_{GS} - V_t\big)^2$

$g_m = 2K\big(V_{GS} - V_t\big)$

$V_{BE} < 0.7 \text{ V}$

$$I_B > 0 \qquad V_{CE} > 0.2 \text{ V}$$

$$I_B > 0 \qquad 0 < I_C < \beta\, I_B$$

$I_C = \beta\, I_B$

$V_A - V_{CE} \approx (V_B - 0.7 \text{ V})\big(1 + \frac{R_C}{R_E}\big)$ if $R_B \ll \beta R_E$ and $\beta \gg 1$

$h_{ie} \approx \frac{nV_T}{I_B}$ ($n = 1$ usually)

$h_{fe} \approx \beta$

$I_B = I_s\big(e^{V_{BE}/nV_T} - 1\big)$

$A_I = \frac{A_V Z_{in}}{R_L}$

$A_P = A_V A_I$