

## Third Quiz

- REMARKS:
1. Hand held non-communicating calculator is allowed,
  2. Closed book quiz,
  3. Formula sheets are attached,
  4. Marks distribution:
    - Question #1: 3 points
    - Question #2: 7 points
  5. Justify all your answers.

# 1	
# 2	

1. The MOSFETs in the circuit of figure 1 are both biased in the active region. Sketch the (small signal) AC model of the circuit in its simplified ladder form. Assume the capacitors are all *very large*.

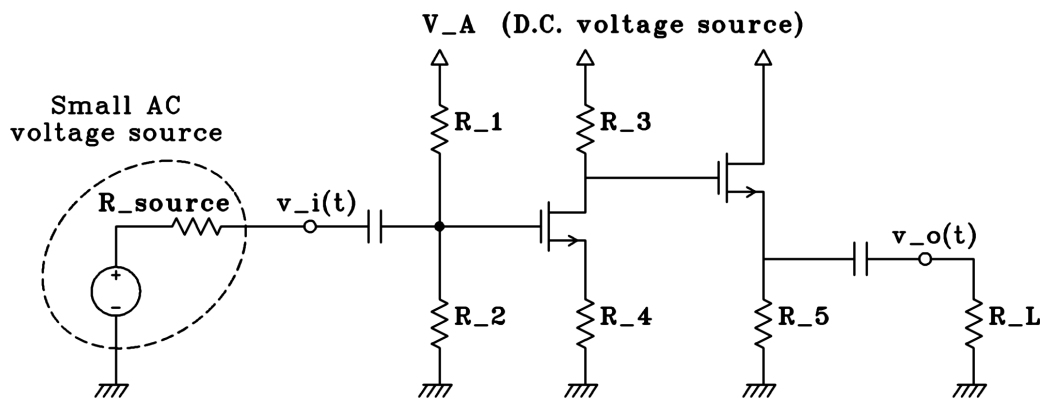


Figure 1:

Name: \_\_\_\_\_

College Number: \_\_\_\_\_

2. The parameters of the MOSFETs in the circuits of figure 2 are:

$$V_t = 2 \text{ V}$$

$$K = 2 \text{ mA/V}^2$$

- (a) Show that the voltage at the gate of the MOSFET is  $V_G = 5$  volts in the circuit of figure 2(a).
- (b) Calculate the Q-point ( $I_D$ ,  $V_{GS}$ ,  $V_{DS}$ ) of the MOSFET in the circuit of figure 2(a).
- (c) We wish to bias the same MOSFET at the same Q-point using only one voltage source as shown in figure 2(b). Calculate the required values of resistors  $R_1$ ,  $R_2$  in such a way that  $R_1 \parallel R_2 = 100 \text{ k}\Omega$ .

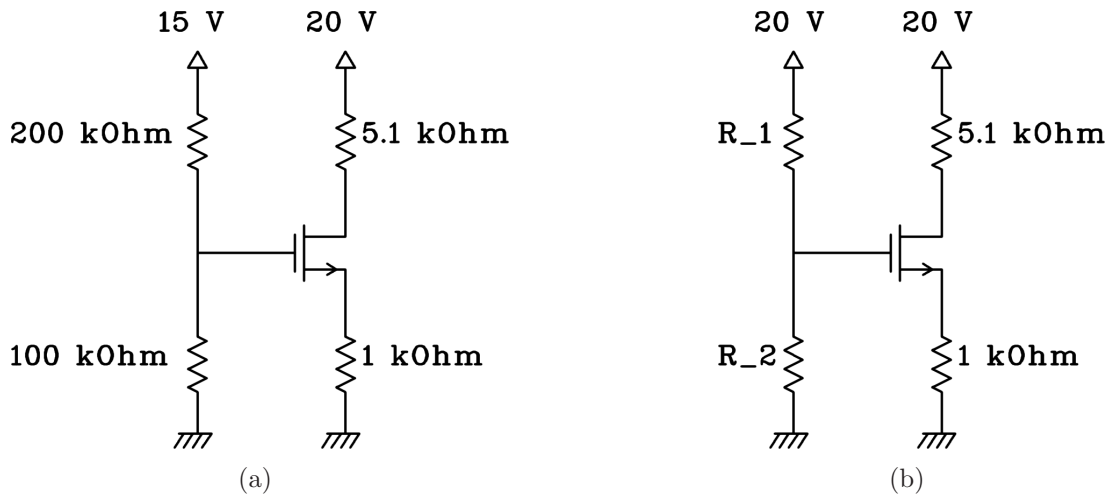


Figure 2:

END

## Formula Sheets

$$\cos \theta = \sin(\theta + 90^\circ)$$

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

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

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

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

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

$$v = Ri$$

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

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

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

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

$$q = C v$$

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

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

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

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

$$\begin{aligned} V_{GS} &> V_t \\ V_{DS} &> V_{GS} - V_t \end{aligned}$$

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

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

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

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

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

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

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

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

$$\mathbf{Z}_R = R$$

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

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

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

$$v(\infty) + (v(0^+) - v(\infty)) e^{-t/\tau}$$

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

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

$$V_T \approx 25.2 \text{ mV at } 20^\circ \text{C}$$

$$R_{dynamic} = \frac{nV_T}{I_D + I_s} \approx \frac{nV_T}{I_D}$$

$$\begin{aligned} V_{GS} &> V_t \\ 0 &< V_{DS} < V_{GS} - V_t \end{aligned}$$

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

## Formula Sheets (continued)

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

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

$$\begin{aligned} I_B &> 0 \\ V_{CE} &> 0.2 \text{ V} \end{aligned}$$

$$\begin{aligned} I_B &> 0 \\ 0 < I_C &< \beta I_B \end{aligned}$$

$$I_C = \beta I_B$$

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

$$h_{fe} \approx \beta$$

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

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

$$A_P = A_V A_I$$

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

For the CMOS inverter:

$$NM_H = V_{oH} - V_{iH} \qquad NM_L = V_{iL} - V_{oL}$$

where

$$\left. \frac{dV_o}{dV_i} \right|_{V_i=V_{iL}} = -1 \text{ et } V_{iL} \equiv \text{logic 0}$$

$$\left. \frac{dV_o}{dV_i} \right|_{V_i=V_{iH}} = -1 \text{ et } V_{iH} \equiv \text{logic 1}$$

