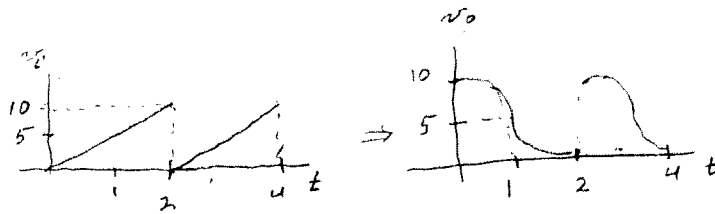


#1. a)



b), @ $t=0$, M_p is ohmic as $V_{SG}=10$, $V_{SD}=0$ while @ $t=1$, $v_i = v_o = 5 \Rightarrow |V_{SG}| - |V_{TDp}| < |V_{SD}|$ & between $t=0$ & $t=1$, M_p switches from ohmic to saturation, this being when $|V_{SG}| - |V_{TDp}| = |V_{SD}| \Rightarrow V_{DD} - v_i - |V_{TDp}| = V_{DD} - v_o$ and

$$I_{SDp} = \frac{K_P}{2} \left(\frac{W}{L} \right) (V_{DD} - v_o)^2 (1 + \lambda [V_{DD} - v_o])$$

so we need v_o so we

i. need regime of M_n at $v_i = v_o - |V_{TDp}| = v_o - V_{TDn}$ or $v_i - V_{TDn} = v_o - 2V_{TDn} < v_o$
 $\equiv V_{GSn} - V_{TDn} < V_{DSn} \Rightarrow M_n$ saturation

$$= I_{DSn} = \frac{K_P}{2} \left(\frac{W}{L} \right) (v_o - 2V_{TDn})^2 (1 + \lambda v_o)$$

as $\lambda v_o < 10^{-5}$ can ignore, $\Rightarrow I_{SDp} = I_{DSn} \Rightarrow (V_{DD} - v_o)^2 = (v_o - 2V_{TDn})^2$

use $\pm V$ as M_p & M_n are on $\Rightarrow V_{DD} - v_o = v_o - 2V_{TDn} \Rightarrow 2v_o = V_{DD} + 2V_{TDn}$

from $v_i = v_o - |V_{TDp}| \Rightarrow v_i = \frac{(V_{DD} + 2V_{TDn})}{2} - V_{TDn} = V_{DD}/2$

$$\Rightarrow v_i = 5V$$

#2. as $V_{DS} = V_{GS} > V_{GS} - V_{TO}$ both M_{n1} & M_{n2} are in saturation with bias current $I_B \Rightarrow$

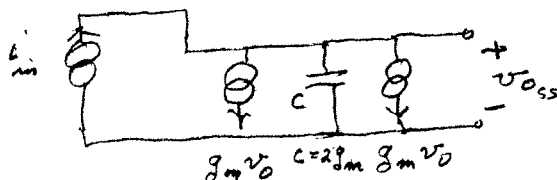
$$I_B = \frac{K_P W}{2 L} (V_{GS} - V_{TO})^2 (1 + \lambda V_{DS}) \approx \frac{K_P W}{2 L} (V_{GS} - V_{TO})^2$$

$$\Rightarrow V_{GS} - V_{TO} = \sqrt{\frac{I_B}{\frac{K_P W}{2 L}}} = \sqrt{\frac{6 \times 10^{-4}}{\frac{3}{2} \times 10^{-4}}} = \sqrt{4} = 2V$$

$$\text{We need } g_m = \frac{\partial I_{DS}}{\partial V_{GS}} = 2 \frac{I_B}{(V_{GS} - V_{TO})} = \frac{2 \times 0.6 \times 10^{-3}}{2} = 6 \times 10^{-4}$$

$$\text{Here } g_o = \frac{\partial I_D}{\partial V_{DS}} = \frac{I_B}{\lambda} \cdot \frac{1}{(1 + \lambda V_{DS})} \approx 0$$

The equivalent circuit for small signal i_{in} is



$$\text{By KCL: } i_{in} = 2 g_m v_{oss} + C \frac{dv_{oss}}{dt} = \left(\frac{dv_{oss}}{dt} + v_{oss} \right) 2 g_m = 2 \times 10^{-4} \sin t$$

$$\Rightarrow \frac{dv_{oss}}{dt} + v_{oss} = \frac{2 \sin t}{2 \times 6} = \frac{1}{6} \sin t$$

To solve:

$$\text{Let } v_{oss}(t) = A \cos t + B \sin t \Rightarrow \frac{dv}{dt} = -A \sin t + B \cos t$$

$$\Rightarrow (-A + B) \sin t + (A + B) \cos t = \frac{1}{6} \sin t \Rightarrow$$

$$A + B = 0 \Rightarrow B = -A \text{ \& } -A + B = -2A = \frac{1}{6} \Rightarrow A = -\frac{1}{12}, B = \frac{1}{12} = 0.0833$$

$$\Rightarrow v_{oss}(t) = (-\sin t + \cos t) \frac{1}{12}$$

The total $v_o(t)$ includes bias, $V_{o_{bias}} = V_{GS} = 2 + V_{TO} = 3$

$\Rightarrow$

$$v_o(t) = 3 + \frac{1}{12} (-\sin t + \cos t)$$

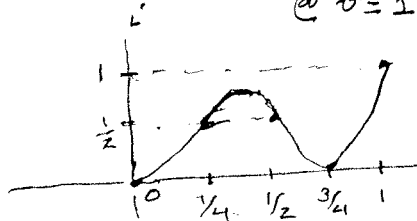
#3.

a). $i = v(1 + \sin 2\pi v)$, an increasing sin with v .

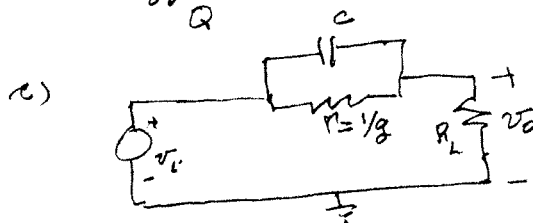
Key values: @ $v=0$, $i=0$, @ $v=\frac{1}{4}$, $i=\frac{1}{4}(1+1)=\frac{1}{2}$

@ $v=\frac{1}{2}$, $i=\frac{1}{2}(1+0)=\frac{1}{2}$, @ $v=\frac{3}{4}$, $i=\frac{3}{4}(1-1)=0$

@ $v=1$, $i=1(1+0)=1$



b) $g = \frac{\partial i}{\partial v} = (1 + \sin 2\pi v) + v(2\pi \cos 2\pi v) = 1 + \sin 2\pi v + 2\pi v \cos 2\pi v$



by voltage divider action

$$v_o = \frac{R_L}{R + \frac{1}{sC}} v_i = \frac{sCR_L}{sCR + 1} v_i$$

$$\Rightarrow T(s) = \frac{sCR_L}{s + g/C}$$

d) If Q point $v_Q = \frac{1}{2} \Rightarrow i_Q = \frac{1}{2} \Rightarrow R_L$ for

$$\frac{-1}{R_L} = \text{slope} = \frac{0 - 1 \text{ amp}}{1 \text{ v} - 0 \text{ v}} = -1$$

$$\Rightarrow R_L = 1 \Omega$$

$$\text{and } g = 1 + \sin 2\pi \cdot \frac{1}{2} + 2\pi \cdot \frac{1}{2} \cos 2\pi \cdot \frac{1}{2} = 1 - \pi < 0$$

$$\therefore T(s) = \frac{s(1 \times (1 - \pi))}{s + (1 - \pi)} = \frac{-2.142s}{s - 2.142}$$

zero at $s=0 \Rightarrow$ DC won't affect small signal
pole at $s = \pi - 1 > 0 \Rightarrow$ unstable $\Rightarrow$ will oscillate between equilibrium

