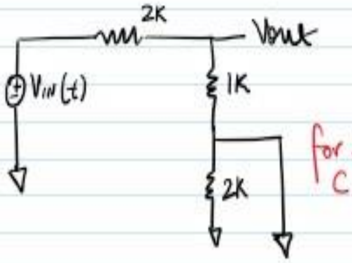
SPRING 2024

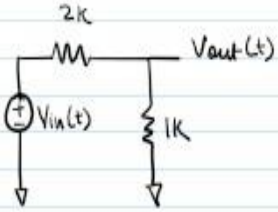
EE330 – Homework 9

1.)

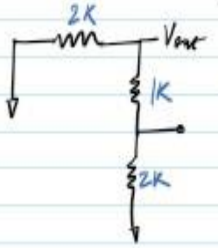
a)



for small signal
C very large = AC gnd



b.) For $V_{in}(t) = 0$ we get quiescent output voltage



Here, we see that quiescent voltage of $V_{out}(t) = 0V$.

c.) For small signal voltage gain

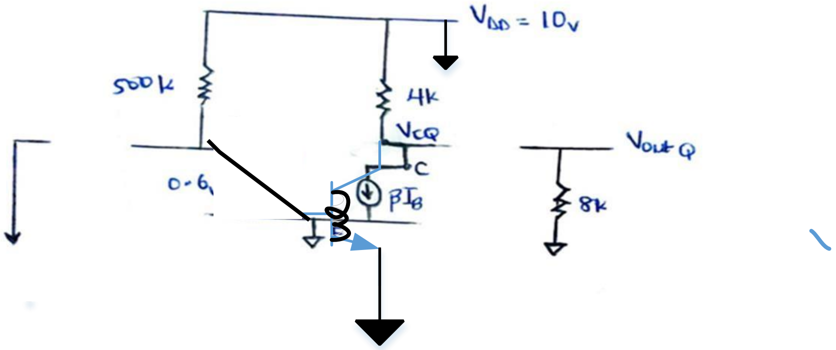
$$A_V = \frac{1K}{(1+2)K} = \underline{\underline{\frac{1}{3}}}$$

d.) $V_{out} = A_V V_{IN}(t)$

$V_{out} = \frac{2}{3} \sin 500t$

Problem 2

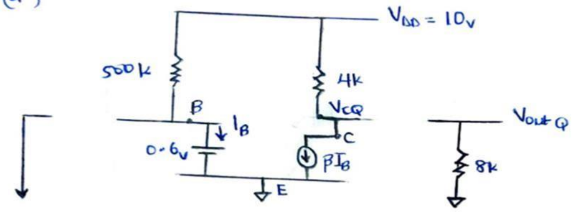
(a)



Problem 2

(b)

(a)



(b) - Assuming Forward Active Region

$\beta = 100$

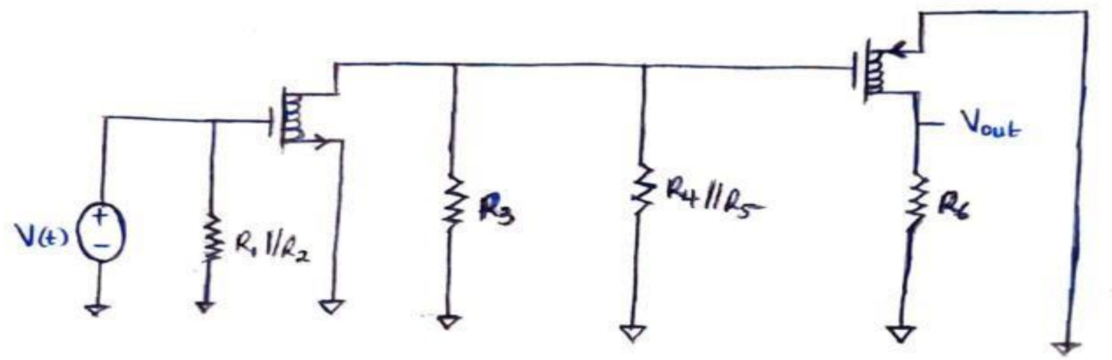
→ $I_B = \frac{10 - 0.6}{500000} = 1.88 \times 10^{-5}$ A

→ $I_C = \beta I_B = 100 \times 1.88 \times 10^{-5} = 1.88 \times 10^{-3}$ A

→ $V_{CQ} = V_{DD} - (I_C \times 4k) = 10 - (1.88 \times 10^{-3} \times 4000) = 2.48_v$

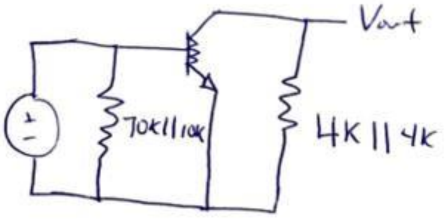
→ Since $I_{RL} = 0$, $V_{out\,Q} = I_{RL} \cdot 8k = 0$

Problem 3



Problem 4

ⓐ Draw the small signal equivalent circuit



ⓑ determine Vc and Vout

$$\boxed{V_{out} = 0V}$$

$$\frac{32 - V_B}{70k\Omega} - \frac{V_B}{10k} + \beta\left(\frac{32 - V_B}{70k\Omega} - \frac{V_B}{10k}\right) = \frac{V_B - 0.6V}{2k}$$

$$V_B = 3.859V$$

$$I_C = \frac{32V - V_C}{4k\Omega}$$

$$I_C = B I_B \quad \Rightarrow I_C = 100(16.114uA) = 1.611mA$$

$$I_B + \frac{3.859}{10k} = \frac{32 - 3.859}{70k}$$

$$I_B = 16.114uA$$

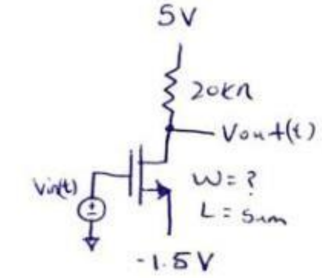
$$I_C = 1.611mA = \frac{32V - V_C}{4k\Omega}$$

$$\boxed{V_C = 25.55V}$$

Alternately, if we assume IB is negligible compared to the current through the 70K resistor, the voltage at the base is, by voltage divider, ((1/8)*32V=4V. Thus the emitter voltage is 4V-0.6V=3.4V. So the current in the emitter , IE=3.4V/2K=1.7mA. But since β is large, IC=IE. Thus VC=32V-IC*4K=25.6V.

Note this solution is somewhat simpler and the results are about the same as that obtained by including the base current.

Problem 5



(a.) determine the width so that $I_d = 0.1mA$

$u_{cox} = 100uA/V^2$ Assume Saturation

$V_{tn} = 0.75V$

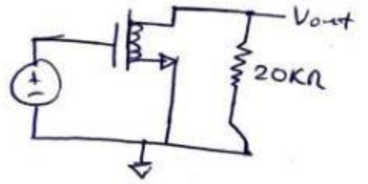
$$I_D = \frac{U_{ncox}}{2}\left(\frac{W}{L}\right)(V_{GS}-V_{tn})^2$$

$$0.1mA = \frac{100uA/V^2}{2}\left(\frac{W}{5um}\right)(1.5-0.75)^2$$

$$0.1mA = 50uA/V^2\left(\frac{W}{5um}\right)(0.75V)^2$$

$$W = \frac{0.1mA \cdot 5um}{50uA/V^2 \cdot (0.75V)^2} = \underline{17.78um}$$

(b) Small signal equivalent circuit



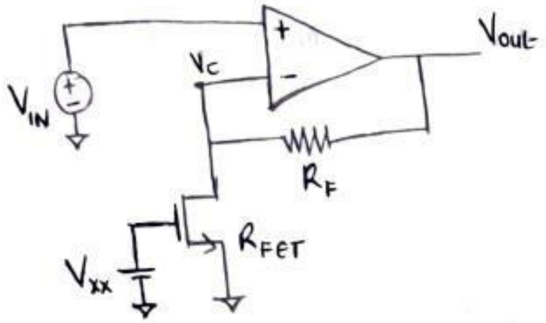
(c) determine small signal voltage gain

$$A_V = \frac{2\,I_{dQ}R}{[V_{SS}+V_T]} = \frac{2(0.1mA)(20k\Omega)}{[-1.5V+0.75V]} = -5.33$$

(d) Determine THD

$$THD = \frac{V_m}{4(V_{GS}-V_T)} = \frac{200mV}{4(1.5V-0.75V)} = 0.067 \simeq 6.7\%$$

Problem 6



* Assuming the amplifier is ideal

$$V_{IN} = V_C \quad — (1)$$

* $V_C = V_{DS}$ of the mosfet

V_{gs} of Mosfet $= V_g - V_s = 2.5 - 0 = 2.5\,V$

* for the Mosfet to be in saturation,

$$V_{DS} \geqslant V_{gs} - V_{T_n}$$

Since $V_{DS} = V_C = V_{IN}$, thus $V_{DS} < 10\,mV$

$\therefore \; V_{DS} \leq V_{gs} - V_{T_n} \; \Big\}$ The transistor is in triode region

(a) If $V_{xx} = 2.5\,v$, the transistor can be represented as a resistor by the channel resistance

$$R_{ch} = \frac{1}{\mu C_{ox} \frac{W}{L}(V_{gs} - V_T)} = \frac{1}{100\times10^{-6} \times \frac{12}{1} \times (2.5 - 0.75)}$$

$$R_{ch} = 476.19\,\Omega$$

$$\text{Voltage Gain} = 1 + \frac{R_F}{476.19\,\Omega}$$

(b) From the R_{ch} equation, we notice that as V_{gs} increases, R_{ch} decreases; therefore, the gain of the noninverting amplifier increases

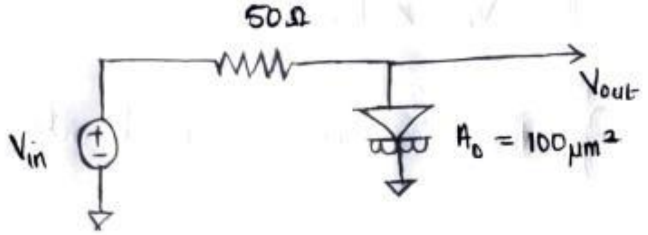
Problem 7

(a) No DC current goes through the capacitor

$$\rightarrow I_D = I_B = J_S A\left(e^{\frac{V_D}{V_t}} - 1\right)$$

$$\rightarrow V_D = V_t \ln\left(\frac{I_B}{J_S A} + 1\right) = 0.026 \ln\left(\frac{1\times10^{-3}}{10^{-14}\times100} + 1\right) = 0.539\,V$$

(b)



(c) $$\frac{(V_{out} - V_{in})}{50} + \frac{V_{out}}{R_D} = 0$$

$$\rightarrow V_{out}\left(\frac{1}{50} + \frac{1}{R_D}\right) = \frac{V_{in}}{50}$$

$$\rightarrow \frac{V_{out}}{V_{in}} = \frac{1}{50\left(\frac{1}{50} + \frac{1}{R_D}\right)} = \frac{1}{1 + \frac{50}{R_D}}$$

But $$R_D = \frac{V_t}{I_{diode}} = \frac{0.026}{0.001} = 26\,\Omega$$

$$\Rightarrow \quad \frac{V_{out}}{V_{in}} = \frac{1}{1 + \frac{50}{26}} = 0.342$$

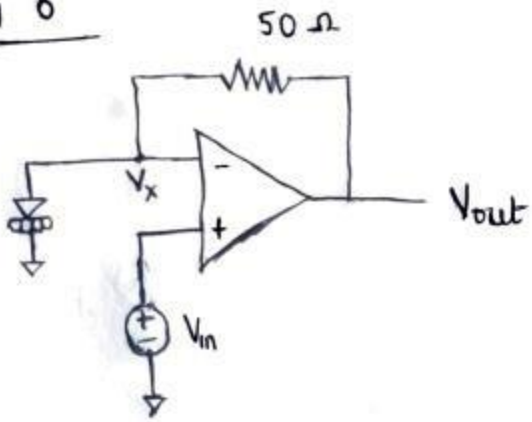
(d) $$R_D = \frac{0.026}{0.005} = 5.2\,\Omega$$

$$\frac{V_{out}}{V_{in}} = \frac{1}{1 + \frac{50}{5.2}} = 0.0942$$

Problem 8

(a)

$A_D = 400 \mu m^2$



(b) From the small signal equivalent circuit,

$$\frac{(V_x - V_{out})}{50} + \frac{V_x}{R_D} = 0$$

Assuming the amplifier is ideal, $V_x = V_{in}$

$$\rightarrow \quad V_{in}\left(\frac{1}{50} + \frac{1}{R_D}\right) = \frac{V_{out}}{50}$$

$$\rightarrow \quad \frac{V_{out}}{V_{in}} = 1 + \frac{50}{R_D}$$

$$R_D = \frac{V_t}{1mA} = \frac{0.026}{0.001} = 26\,\Omega$$

$$\rightarrow \quad \frac{V_{out}}{V_{in}} = 1 + \frac{50}{26} = 2.923$$

(c) $$\frac{V_{out}}{V_{in}} = 1 + \frac{50}{R_D}$$

$$R_D = \frac{0.026}{10\times10^{-3}} = 2.6$$

$$\Rightarrow \quad \frac{V_{out}}{V_{in}} = 1 + \frac{50}{2.6} = 20.23$$