

$$+2k(I) + 8 + 2k(I) = 0$$

$$4k(I) = -8$$

$$I = -\frac{8}{4k} = -2 \text{ m}$$

$$V_G = 2k(I) = -4 \text{ V}$$

$$V_{GS} = -4 - [3.6k(I_D) + 0.8 - 15] = 10.2 - 3.6k(I_D)$$

$$I_D = \frac{1}{2} K_n \left(\frac{W}{L}\right) (V_{GS} - V_t)^2 = \frac{1}{2} (1 \text{ m}) (10.2 - 3.6k(I_D) - 1)^2 = (0.5 \text{ m}) (9.2 - 3.6k(I_D))^2$$

$$2000 I_D = 84.64 - 2 \cdot 9.2 \cdot 3.6k I_D + 12960000 I_D^2$$

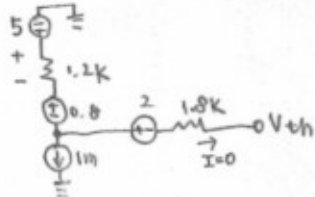
$$12960000 I_D^2 - 68240 I_D + 84.64 = 0$$

$$I_D = \frac{68240 \pm \sqrt{68240^2 - 4 \cdot 12960000 \cdot 84.64}}{2 \cdot 12960000} = 0.003265432 \text{ A} \approx 0.002$$

$$V_{GS} = 10.2 - 3.6k(0.003265432) = -1.5 < (V_t = 1) \rightarrow \text{off}$$

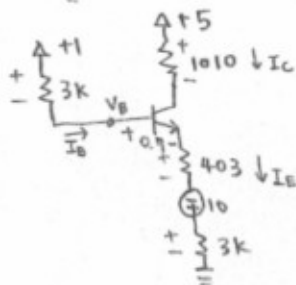
(i) $\therefore I_{\text{diode}} = I_D = I_S = 0.002 \text{ A} = 2 \text{ mA} \checkmark$

$$V_{GS} = 10.2 - 3.6k(0.002) = 3 > (V_t = 1) \checkmark \rightarrow \text{on}$$



$$V_{th} = -2 - 0.8 - 1.2k(1 \text{ m}) + 5 = 1 \text{ V} \checkmark$$

$$R_{th} = 1.8k + 1.2k = 3k \Omega \checkmark$$



$$+1 - 3k(I_B) - 0.7 - 403(I_E) + 10 - 3k(I_E) = 0$$

$$3k(I_B) + 3403(I_E) = 10.3$$

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

$$I_E = \frac{10.3}{\frac{3k}{100} + 3403} = 0.003000291 \text{ A} = 3.0003 \text{ mA} \checkmark$$

$$I_B = \frac{I_E}{\beta + 1} = 0.030003 \text{ mA} = 30.003 \mu\text{A} \checkmark$$

(ii) $\therefore V_B = -3k(I_B) + 1 = 1 - 3k(30.003 \mu) = 0.909991 \text{ V} \checkmark$

$$I_C = \frac{\beta}{\beta + 1} I_E = 2.97297 \text{ mA}$$

(iii) $\therefore V_{out} = V_C = 5 - 1010(I_C) = 5 - 1010(2.97297 \text{ m}) = 1.9973003 \text{ V} \checkmark$

(b) $V_D = 15 - 1k(I_D) = 15 - 1k(2 \text{ m}) = 13 \text{ V}$

$$V_S = 3.6k(I_D) + 0.8 - 15 = 3.6k(2 \text{ m}) - 14.2 = -7 \text{ V}$$

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

$$(13 - (-7) = 20) > (3 - 1 = 2)$$

$$\rightarrow \therefore M1 \text{ is SAT} \checkmark$$

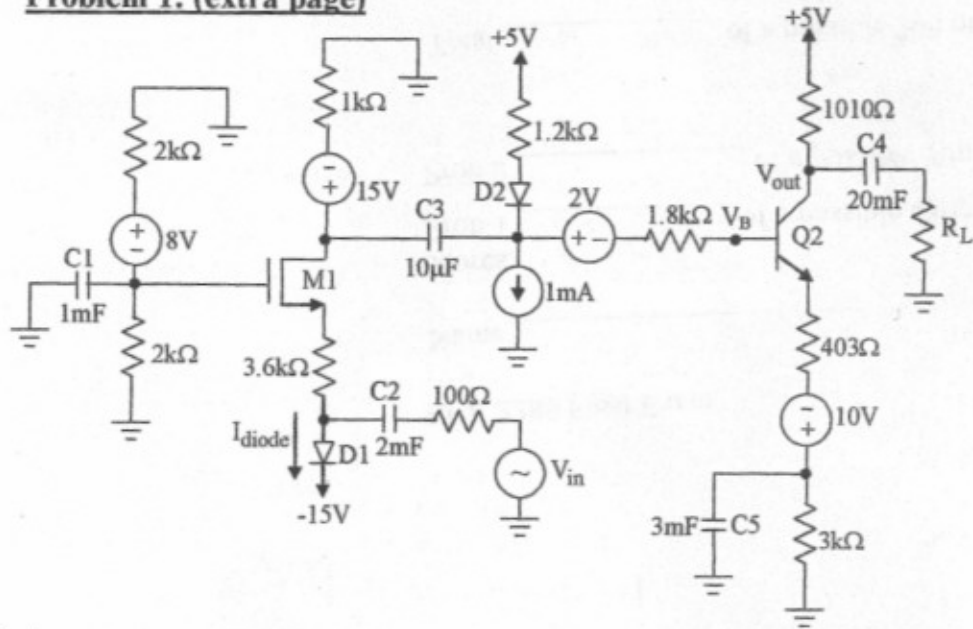
$$V_E = V_B - 0.7 = 0.209991 \text{ V}$$

$$\therefore V_C > V_B > V_E$$

$$1.9973003 > 0.909991 > 0.209991$$

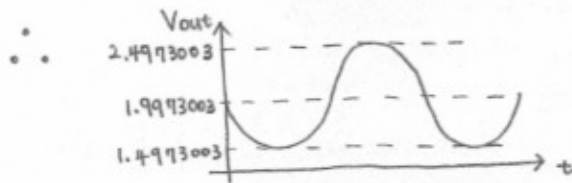
$$\rightarrow \therefore Q_2 \text{ is Active} \checkmark$$

Problem 1: (extra page)

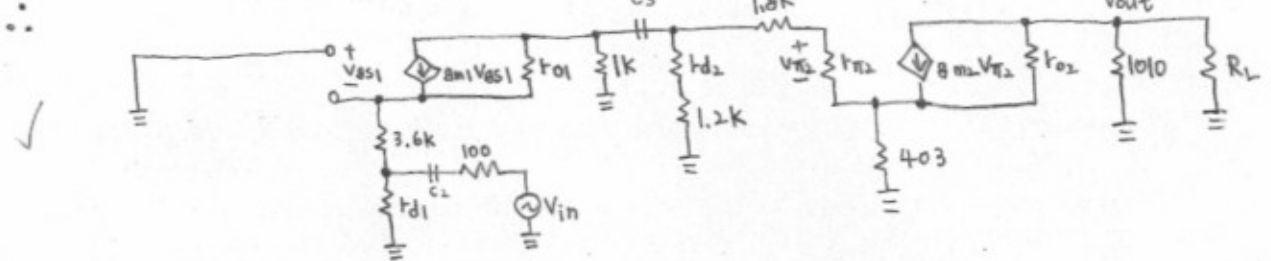


(c) $\frac{V_{out}}{V_{in}} = -500$

$V_{out} = DC + AC = 1.9973003 + (-500 \times 0.001) = 1.9973003 - 0.5$



(d)



(e)

$$\begin{aligned} \therefore \omega_{LC2} &= \frac{1}{C_2 [100 + [r_{d1} \parallel (3.6k + \frac{1}{8m1})]]} = \frac{1}{2m [100 + [10 \parallel (3.6k + \frac{1}{8m1})]]} \\ &= \frac{1}{2m [100 + [10 \parallel 4.6k]]} = \frac{1}{2m [100 + (28.57142857)]} = 3.8889 \text{ rad/s} \end{aligned}$$

$\times 4.55$
 $\times \text{math} \textcircled{-1}$

$$\begin{aligned} \therefore \omega_{LC3} &= \frac{1}{C_3 [1k + [(r_{d2} + 1.2k) \parallel (1.8k + r_{\pi 2} + (\beta + 1)(403))]]} \\ &= \frac{1}{10\mu [1k + [(1140 + 1200) \parallel (1.8k + 2k + 40300)]]} = \frac{1}{10\mu [1k + [2340 \parallel 44100]]} \\ &= \frac{1}{10\mu [1k + 2222.093023]} = 31.0357 \text{ rad/s} \end{aligned}$$

$$\therefore W_L = 31.0357 \text{ rad/s} \quad \checkmark$$

$$\begin{aligned} \therefore W_L &= 31.04 + 3.9 + 1 + 1 = 37.94 \text{ rad/s} \quad \checkmark \\ &\text{(more accurate)} \end{aligned}$$

$$a) r_d = \frac{nV_T}{i_{DQDC}} = \frac{4(25m)}{100\mu A} = 1k\Omega = r_d \quad \checkmark$$

$$r_{\pi 4} = \frac{\beta}{g_{m4}} = \frac{49}{3.92m} = 12.5k\Omega \quad \checkmark$$

$$r_{\pi 4} = 12.5k\Omega \quad \checkmark$$

$$g_{m4} = \frac{i_c}{V_T} = \frac{98\mu A}{25m} = 3.92m \frac{A}{V} \quad \checkmark$$

$$g_{m4} = 3.92m \frac{A}{V} \quad \checkmark$$

$$i_{c4} = \frac{\beta}{\beta+1} i_{c4} = \left(\frac{49}{50}\right) 100\mu A = 98\mu A$$

$$g_{m5} = \sqrt{2k_n' \left(\frac{W}{L}\right) i_{D5}}$$

$$= \sqrt{2(10m)(20m)}$$

$$g_{m5} = 20m \frac{A}{V} = 9mS \quad \checkmark$$

$$b) R_x = r_d + \frac{r_{\pi 4} + 10k}{\beta + 1}$$

$$= 1k + \frac{12.5k + 10k}{50}$$

$$R_x = 1.45k\Omega \quad \checkmark$$

$$c) R_{in} = 1k + \frac{1}{g_{m3}}$$

$$= 1k + \frac{1}{20m}$$

$$R_{in} = 1.05k\Omega \quad \checkmark$$

$$d) R_{out} = 10k || (1k + 3k)$$

$$= 10k || 4k$$

$$R_{out} = 3.2k\Omega \quad \checkmark$$

$$e) V_{out} = \frac{-g_{m5} V_{q55} \cdot 3k}{20k} \left(\frac{10k}{\beta+1} \right)$$

$$= -g_{m5} V_{q55} (2.4k)$$

$$V_{q55} = -g_{m3} V_{q53} \left(\frac{10k}{\beta+1} + \frac{r_{\pi 4}}{\beta+1} + r_d \right)$$

$$= -g_{m3} V_{q53} (1.45k)$$

$$V_{q53} = 0 - (g_{m3} V_{q53} (1k) + V_{in})$$

$$V_{q53} + g_{m3} V_{q53} (1k) = -V_{in}$$

$$V_{q53} = \frac{-V_{in}}{1 + g_{m3}(1k)}$$

$$V_{out} = (-g_{m5})(2.4k)(-g_{m3})(1.45k) \left(\frac{-V_{in}}{1 + g_{m3}(1k)} \right)$$

$$\frac{V_{out}}{V_{in}} = - \frac{(20m)(2.4k)(20m)(1.45k)}{1 + (20m)(1k)}$$

$$\frac{V_{out}}{V_{in}} = -66.29 \frac{V}{V} \quad \checkmark$$

f) IN IDEAL CASES, FOR VOLTAGE AMPLIFICATION YOU WOULD WANT TO HAVE HIGH INPUT IMPEDANCE AND LOW OUTPUT IMPEDANCE. THIS CIRCUIT GIVES A GAIN OF $-66.29 \frac{V}{V}$, BUT I WOULD STILL SAY IT IS NOT A GOOD AMPLIFIER FOR VOLTAGES BECAUSE THIS HAS A LOW INPUT IMPEDANCE AND A HIGH OUTPUT IMPEDANCE, OPPOSITE OF WHAT WE WANT.