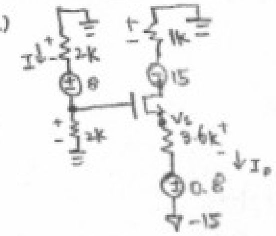
(a)



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

$4k(I)=-8$

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

$V_G=2k(I)=-4V$

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

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

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

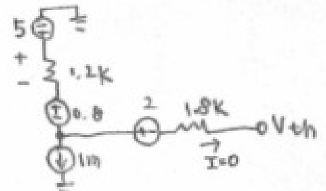
$12960000\,I_D^2-68240\,I_D+84.64=0$

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

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

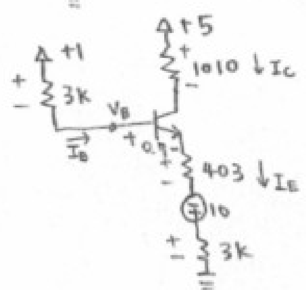
(i) $\therefore I_{diode}=I_D=I_S=0.002A=\boxed{2mA}$ ✓

$V_{GS}=10.2-3.6k(0.002)=3>(V_t=1)$ ✓ ↳ on



$V_{th}=-2-0.8-1.2k(1m)+5=1V$ ✓

$R_{th}=1.8k+1.2k=3k\Omega$ ✓



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

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

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

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

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

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

$I_C=\frac{\beta}{\beta+1}I_E=2.972297mA$

(iii) $\therefore V_{out}=V_C=5-1010(I_C)=5-1010(2.972297m)=\boxed{1.9973003V}$ ✓

(b)

$V_D=15-1k(I_D)=15-1k(2m)=13V$

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

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

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

↳ ∴ M1 is SAT ✓

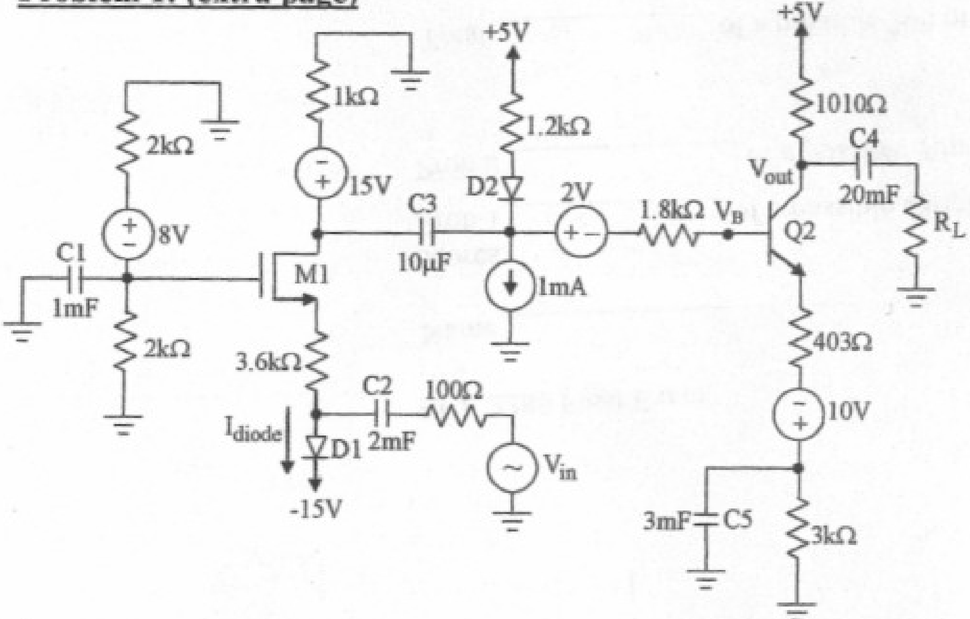
$V_E=V_B-0.7=0.209991V$

$\therefore V_C>V_B>V_E$

$1.9973003>0.909991>0.209991$

↳ ∴ Q_2 is Active ✓

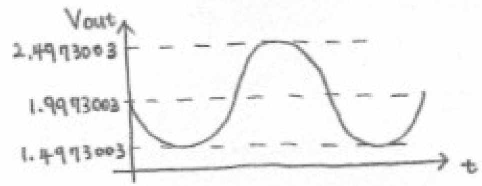
Problem 1: (extra page)



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

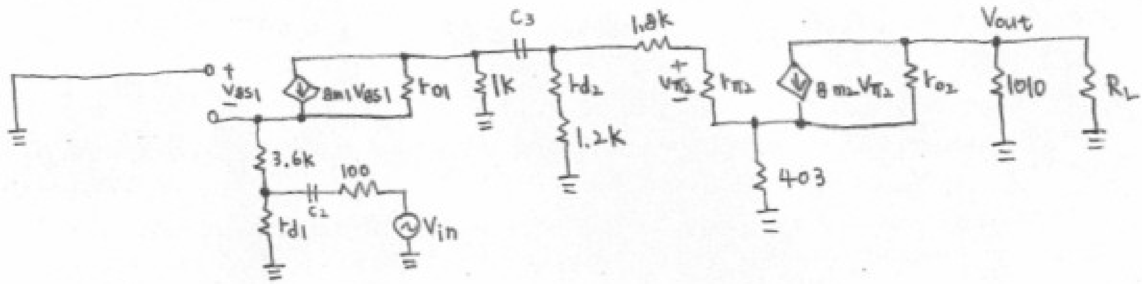
$V_{out} = DC + AC = 1.9973003 + (-500 \times 0.001) = 1.9973003 - 0.5$

$\therefore$



(d)

$\therefore$



(e)

$$\therefore W_{LC_2} = \frac{1}{C_2[100 + [r_{d1} \,//\, (3.6k + \frac{1}{g_{m1}})]]} = \frac{1}{2m[100 + [10 \,//\, (3.6k + \frac{1}{1m})]]}$$

× 4.55

$$= \frac{1}{2m[100 + [10 \,//\, 4.6k]]} = \frac{1}{2m[100 + (28.57142857)]} = 3.8889 \text{ rad/s}$$

× math (-1)

$$\therefore W_{LC_3} = \frac{1}{C_3[1k + [(r_{d2} + 1.2k) \,//\, (1.8k + r_{\pi 2} + (\beta+1)(403))]]}$$

$$= \frac{1}{10\mu[1k + [(1140 + 1200) \,//\, (1.8k + 2k + 40300)]]} = \frac{1}{10\mu[1k + [2340 \,//\, 44100]]}$$

$$= \frac{1}{10\mu[1k + 2222.093023]} = 31.0357 \text{ rad/s}$$

$\therefore W_L = 31.0357$ rad/s ✓

or

$\therefore W_L = 31.04 + 3.9 + 1 + 1 + 1 = 37.94$ rad/s ✓

(more accurate)

a) $r_d = \frac{nV_T}{i_{DIODE}} = \frac{4(25m)}{100\mu} = \boxed{1k\Omega = r_d}$ ✓

$r_{\pi 4} = \frac{\beta}{g_{m4}} = \frac{49}{3.92m}$

$\boxed{r_{\pi 4} = 125k\Omega}$ ✓

$g_{m4} = \frac{i_c}{V_T} = \frac{98\mu}{25m}$

$\boxed{g_{m4} = 3.92m\,\frac{A}{V}}$ ✓

$i_{c4} = \frac{\beta}{\beta+1} i_{E4}$

$i_c = \left(\frac{49}{50}\right) 100\mu A = 98\mu A$

$g_{m3} = \sqrt{2k_n'\left(\frac{W}{L}\right) i_D}$

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

$\boxed{g_{m3} = 20m\,\frac{A}{V} = g_{m5}}$ ✓

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

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

$\boxed{R_x = 1.45k\Omega}$ ✓

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

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

$\boxed{R_{IN} = 1.05k\Omega}$ ✓

d) $R_{OUT} = 16k \,||\, (1k + 3k)$

$= 16k \,||\, 4k$

$\boxed{R_{OUT} = 3.2k\Omega}$ ✓

e) $V_{OUT} = \frac{-g_{m5} V_{gs5}\, 3k}{20k}(16k)$

$= -g_{m5} V_{gs5} (2.4k)$

$V_{gs5} = -g_{m3} V_{gs3}\underbrace{\left(\frac{10k}{\beta 11} + \frac{r_{\pi 4}}{\beta 11} + r_d\right)}_{R_x}$

$= -g_{m3} V_{gs3} (1.45k)$

$V_{gs3} = 0 - (g_{m3} V_{gs3}(1k) + V_{IN})$

$V_{gs3} + g_{m3} V_{gs3}(1k) = -V_{IN}$

$V_{gs3} = \frac{-V_{IN}}{1 + g_{m3}(1k)}$

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

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

$\boxed{\frac{V_{OUT}}{V_{IN}} = -66.29\,\frac{V}{V}}$ ✓

✓ 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.