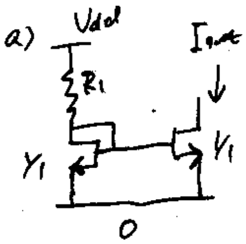
HW5 Solution EE140 Mike Chen



1)

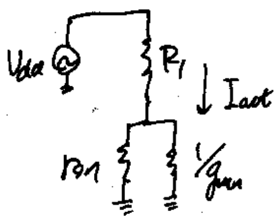
a)




$K_n' = 200\ \mu A/V^2$

$K_p' = 100\ \mu A/V^2$. $I_{out} = 1\ \mu A$. $|V_{tn}| = |V_{tp}| = 0.3\ V$

$$R_1 = \frac{1.2 - 0.3 - \sqrt{\frac{2 \cdot 1\mu A}{K_n' \cdot Y_1}}}{1\ \mu A} = 0.8\ M\Omega$$




Power Supply Sensitivity.

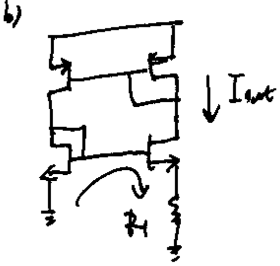
$$\frac{V_{dd}}{R_1 + (r_{on} \parallel \frac{1}{g_{mn}})} \cdot \frac{1}{1} = I_{out}$$

$$r_{on} = \frac{1}{\lambda I_d} = 20\ M\Omega$$

$$g_{mn} = \sqrt{2 \cdot K_n' \cdot \frac{W}{L} \cdot I_d} = 2 \times 10^{-5}. \quad \frac{1}{g_{mn}} = 50\ K$$

$$\therefore \frac{I_{out}}{V_{dd}} \cong \frac{1}{R_1 + \frac{1}{g_{mn}}} = \frac{1}{850K}$$

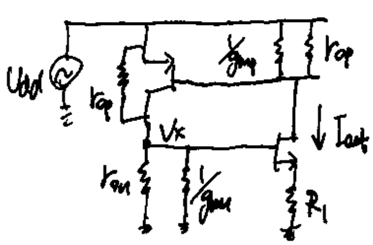
b)




Solve KVL loop, assume $\lambda = 0$. no body effect

$$I_{out} \cdot R_1 + V_{tn} + \sqrt{\frac{2 \cdot I_{out}}{K_n' \cdot 4/1}} = V_{tn} + \sqrt{\frac{2 \cdot I_{out}}{K_n' \cdot Y_1}}$$

$\therefore R_1 = 50\ K\Omega$




Power Supply Sensitivity.

$$\frac{V_{dd} - V_x}{r_{op}} + I_{out} \cdot (r_{op} \parallel \frac{1}{g_{mp}}) \cdot g_{mp} = \frac{V_x}{r_{on} \parallel \frac{1}{g_{mn}}}. \quad (*)$$

$$I_{out} \sim \frac{g_{mn}}{1 + g_{mn} R_1} \cdot V_x. \quad (\text{CS with } R_1 \text{ degeneration}).$$

$r_{op} = \frac{1}{\lambda_p I_o} = 40\,M\Omega$. $g_{mp} = 1.414 \times 10^{-5}$. $1/g_{mp} = 70.7K$ ②

$r_{on} = 20\,M\Omega$ $g_{mn} = 2 \times 10^{-5}$

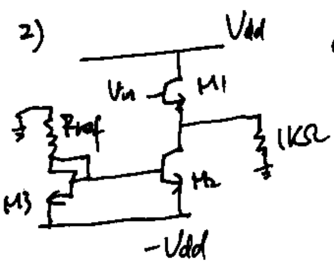
$$I_{out} \sim \frac{2 \cdot 10^{-5}}{1 + 2 \cdot 10^{-5} \cdot 50k} \cdot V_x = 10^{-5} \cdot V_x.$$

$$\therefore (*) \rightarrow \frac{V_{dd} - 10^{5} I_{out}}{40M} + I_{out} = \frac{V_x}{1/g_{mn}} = 2 \cdot I_{out}.$$

$$\frac{V_{dd}}{40M} \sim I_{out}. \quad \therefore \frac{I_{out}}{V_{dd}} = \frac{1}{40M} \text{ ※}$$

Conclusion: 2nd topology has much better power supply insensitivity than 1st topology!

2)




a) $V_{dd} = 1.2V$. $L = 0.13\,\mu m$.

$V_{out}$ swing $-0.8V \sim 0.8V$.

for highest efficiency:

$$V_{out,max} = -I_Q \cdot R_L \Rightarrow -0.8 = -I_Q \cdot 1K.$$

$$I_Q = 0.8\,mA.$$

Also. $V_{out,min} = -V_{dd} + V_{dsat_2} = -0.8$.

$$\therefore 0.4 = \sqrt{\frac{2 \cdot I_Q}{K_n'(\frac{W}{L})_2}} \Rightarrow (\tfrac{W}{L})_2 = (\tfrac{W}{L})_3 = 100 \text{ ※}$$

$$R_{ref} = \frac{1.2 - 0.3 - 0.4}{0.8\,mA} = 625\ (\Omega) \text{ ※}.$$

$V_{out,max} = V_{dd} - V_t - V_{dsat1}$.

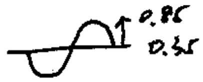
$\therefore \quad V_{dsat1} = 1.2 - 0.3 - 0.8 = 0.1 = \sqrt{\frac{2\cdot(2I_B)}{k'(\frac{W}{L})_1}}$.

$(\frac{W}{L})_1 = 3200$ ※

b)

Output Swing: $-0.8 \sim 0.8V$

Input Swing: $(-0.8+0.3) \sim 1.2V$.

$\therefore$ Input sine wave 


$P_{L,ave} = \frac{1}{2}\frac{V_o^2}{R_L} = \frac{0.64}{2\cdot 1K} = 0.32$ mW ※. spice: 0.325 mW

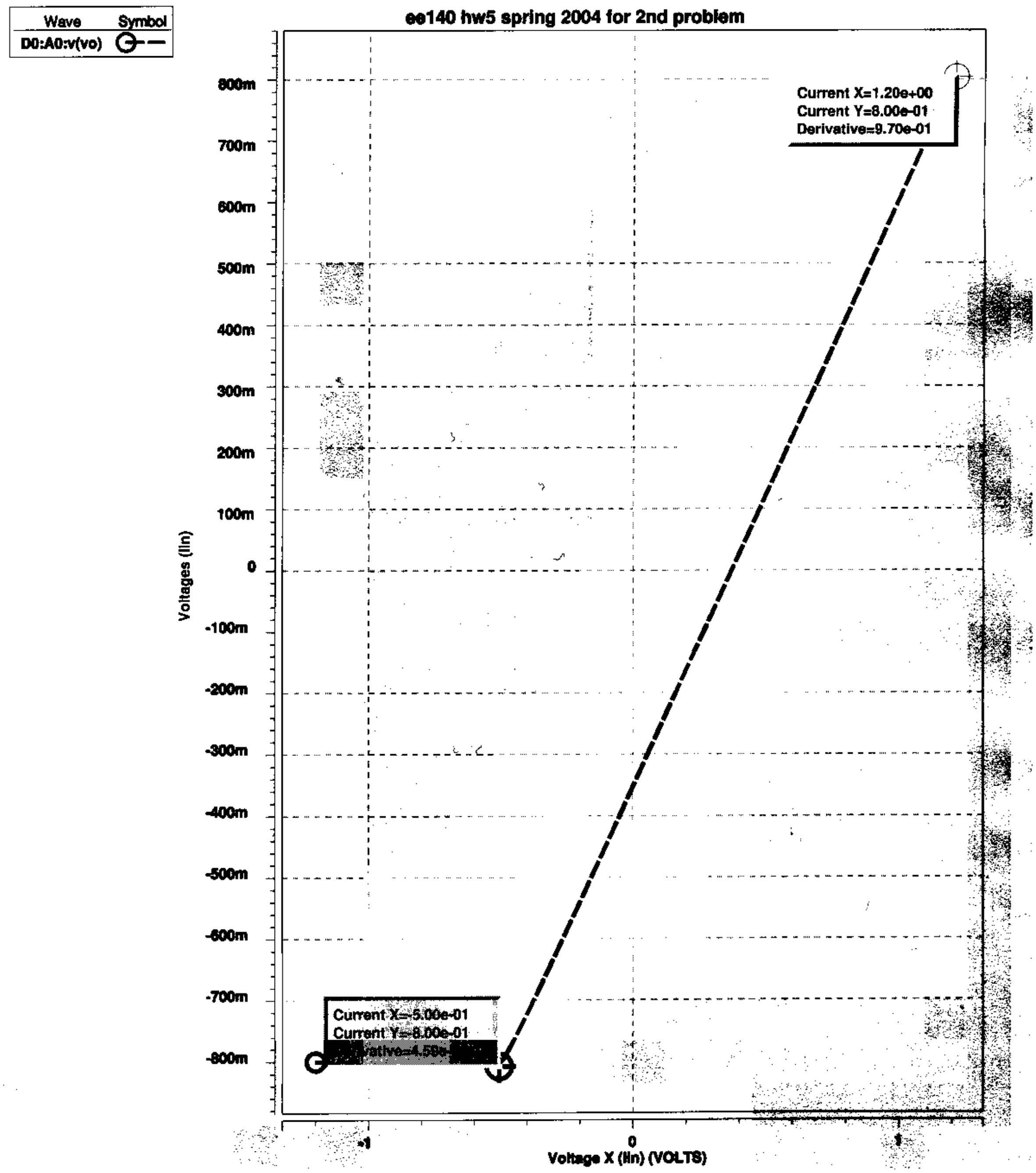
$P_{supply} = 3 \cdot I_B \cdot V_{dd} = 2.88$ mW ※. spice: 2.865 mW

$\eta = \frac{P_{L,ave}}{P_{supply}} = 11.11\%$. ※

Spice: 11.36%

b)

④


ee140 hw5 spring 2004 for 2nd problem
Wave Symbol
D0:A0:v(vo)
Current X=1.20e+00
Current Y=8.00e-01
Derivative=9.70e-01
Current X=-5.00e-01
Current Y=-8.00e-01
800m
700m
600m
500m
400m
300m
200m
100m
0
-100m
-200m
-300m
-400m
-500m
-600m
-700m
-800m
Voltages (lin)
-1
0
1
Voltage X (lin) (VOLTS)

c)

5

EE140 HW5 Spring 2004 for 2nd problem

```
.model nch nmos LEVEL=1 TOX=25 VTO=0.3 KP=100.0e-6 LAMBDA=0
+GAMMA=0.01 PHI=0.6

*-----------------------------------------
vdd vdd 0 1.2
vss vss 0 -1.2
vin vin 0 sin(0.35 0.85 1)

Rref 0 vb 625
Rl 0 vo 1k

M1 vdd vin vo vo nch L=0.13u W=416u
M2 vo vb vss vss nch L=0.13u W=13u
M3 vb vb vss vss nch L=0.13u W=13u

*-----------------------------------------

.dc vin -1.2 1.2 0.01
.tran 1m 1

.meas tran p_load avg p(Rl)    *power to the load
.meas tran p_sup avg power     *power dissipated in supply
.meas tran eff param='100*p_load/p_sup'  *calculate efficiency

.option nomod post
.op
.end
```

```
****** transient analysis          tnom= 25.000 temp= 25.000
******
 p_load= 3.2539E-04  from= 0.0000E+00   to= 1.0000E+00
 p_sup= 2.8648E-03  from= 0.0000E+00   to= 1.0000E+00
 eff= 1.1358E+01
```