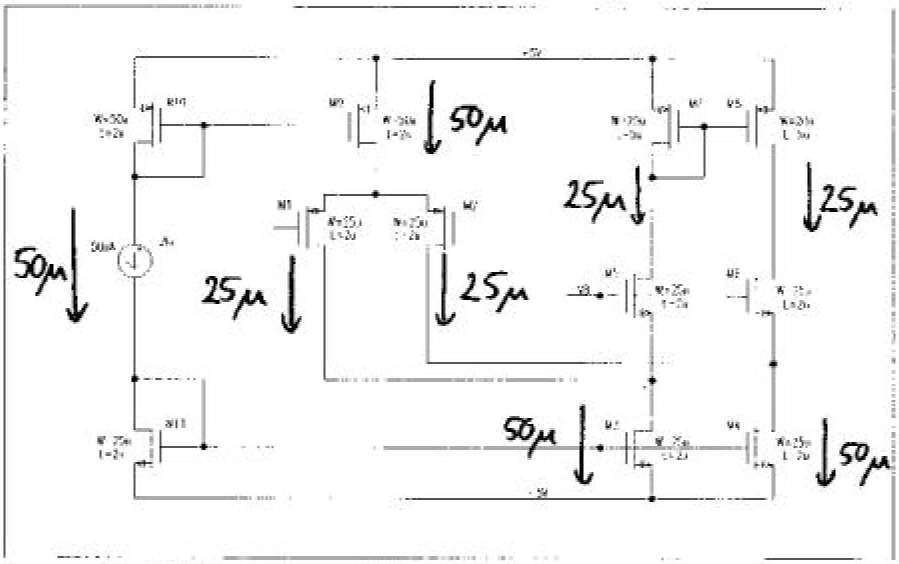
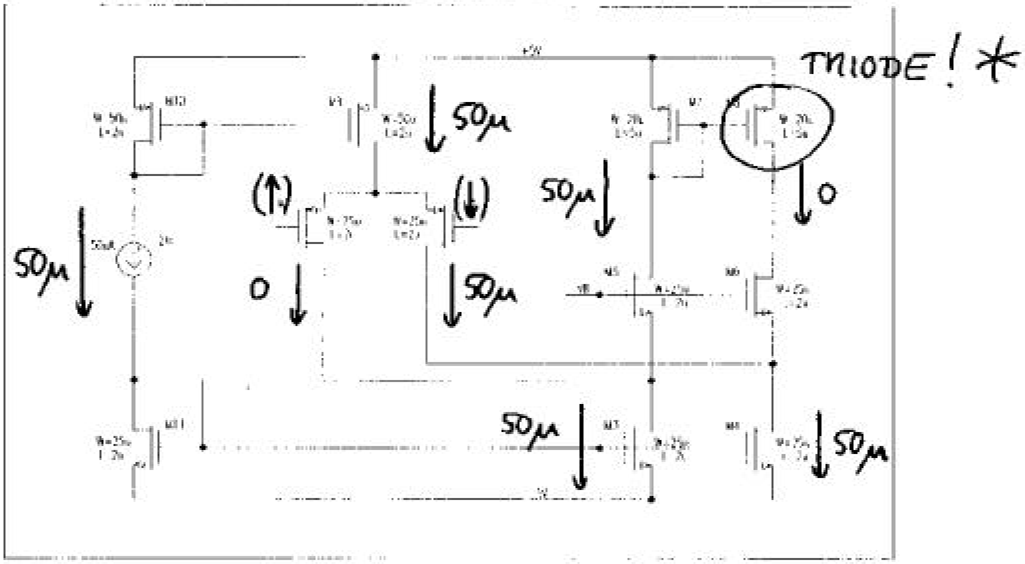
EECS140

Solution HW9

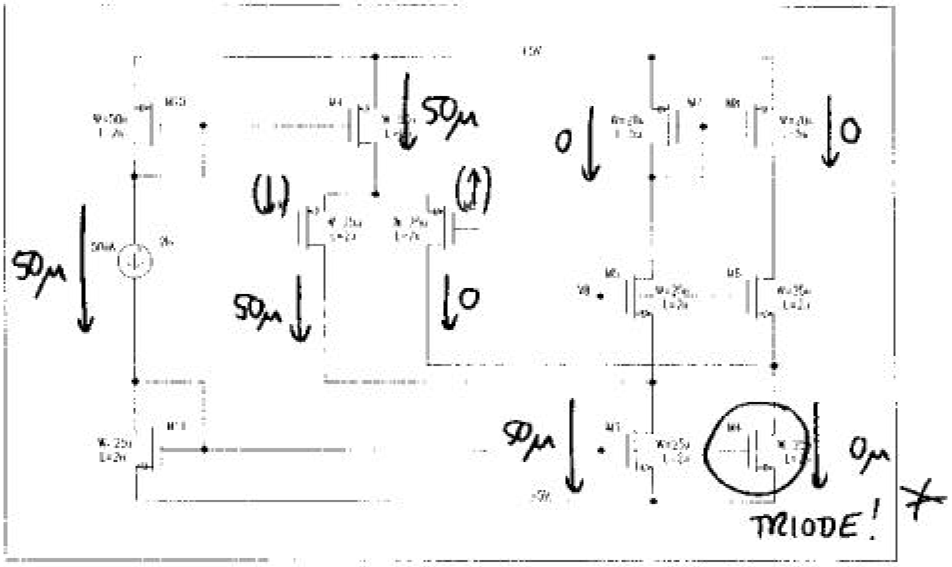
① a) (i)



(ii)



(iii)



* If the output is connected to ground, these devices stay forward active and carry 50μA, which then flows into the output... (another possible solution)

① b) for M3 & M4: $V_{dsat_3} = \sqrt{\frac{2I_D}{k' \frac{W}{L}}} = \sqrt{\frac{2\cdot 50\mu}{200\mu\cdot 12.5}} = 200mV$

for M4 & M5 we have to consider the max. drain current, i.e. $I_{Dmax} = 2I_0$

$$\Rightarrow V_{dsat_5}^{(max)} = \sqrt{\frac{2\cdot 50\mu}{200\mu\cdot 12.5}} = 200mV$$

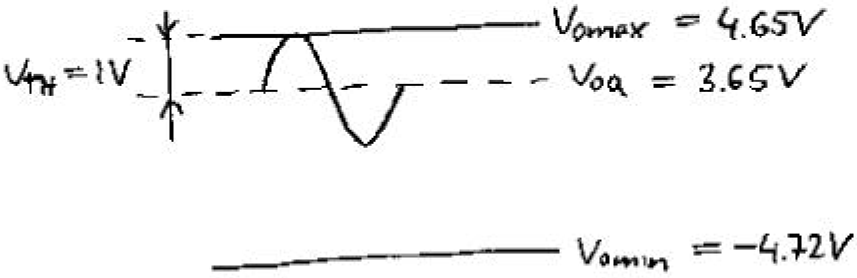
$$\Rightarrow V_{Bmin} = \underset{+VSS}{V_{TH}} + V_{dsat3} + V_{dsat5} = \underline{\underline{-3.6V}}$$

c) neg. swing: $V_{dsat5} = \sqrt{\frac{2\cdot 25\mu}{200\mu\cdot 12.5}} = 141mV = V_{dsat_3}$

$$\Rightarrow V_{omin} = V_{SS} + V_{dsat3} + V_{dsat5} = \underline{\underline{-4.72\ V}}$$

pos. swing: $V_{dsat8} = \sqrt{\frac{2\cdot 25\mu}{100\mu\cdot 4}} = 353mV$

$$\Rightarrow V_{omax} = 5V - 353mV = \underline{\underline{4.65V}}$$



Bias voltage at output: $V_{OQ} = 5V - V_{DS7} = 3.65V$
(symmetry)

⇒ max output amplitude before clipping:

$$\hat{v}_o = V_{Omax} - V_{OQ} = V_{TH} = \underline{\underline{1V}}$$

ⓓ $G_m = g_{m1} = \sqrt{2 I_D k' \frac{W}{L}} = \sqrt{50\mu \cdot 100\mu \cdot 12.5} = 250\mu S$

$R_o = r_{o8} \,||\, g_{m6} r_{o6} r_{o4}$

$r_{o8} = \frac{1}{\lambda I_D} = \frac{1}{0.02 \cdot 25\mu} = 2M\Omega$

$r_{o6} = \frac{1}{0.05 \cdot 25\mu} = 800 K\Omega$

$r_{o4} = \frac{1}{0.05 \cdot 50\mu A} = 400 k\Omega$

$g_{m6} = \sqrt{100\mu \cdot 200\mu \cdot 12.5} = 500\mu S$

$\Rightarrow R_o = 2M\Omega \,||\, \cancel{160M\Omega} \cong 2M\Omega$ (R_o dominated by r_{o8} ...)

$\Rightarrow A_{dmo} = G_m R_o = 250\mu S \cdot 2M\Omega = \underline{\underline{500}}$

ⓔ $V_{OQ} = 3.65V$ at bias point

middle of operating range: $\frac{V_{omax} + V_{omin}}{2} = \frac{4.65 - 4.72}{2} = 35mV$

$\cong 0V$

$\Rightarrow \Delta V_o = 3.65V$ required at the output

$\Rightarrow \Delta V_{id} = \frac{\Delta V_o}{A_{dmo}} = \frac{3.65V}{500} = \underline{\underline{7.3 mV}}$

ⓕ $f_U = \frac{G_m}{2\pi C_L} = \frac{250\mu S}{2\pi 10pF} = \underline{\underline{4MHz}}$

nondominant pole due to current mirror M7–M8:

$f_{p2} = \frac{1}{2\pi} \frac{g_{m7}}{2 C_{gs7}}$

$g_{m7} = \sqrt{50\mu \cdot 100\mu \cdot 4} = 141\mu S$

$C_{gs7} = \frac{2}{3} \cdot 100 \cdot 5fF = 333 fF$

$\Rightarrow f_{p2} = \underline{\underline{33.6 MHz}}$

f) ctd:

(check for second pole due to cascode M5–M6

$$f_{p3} = \frac{1}{2\pi} \frac{\sqrt{25\mu \cdot 200\mu \cdot 12.5}}{\frac{2}{3} \cdot 50.5fF} = \frac{250\mu S}{2\pi \cdot 166.7fF} = 238MHz$$

$f_{p3} \gg f_{p2}$ ✓)

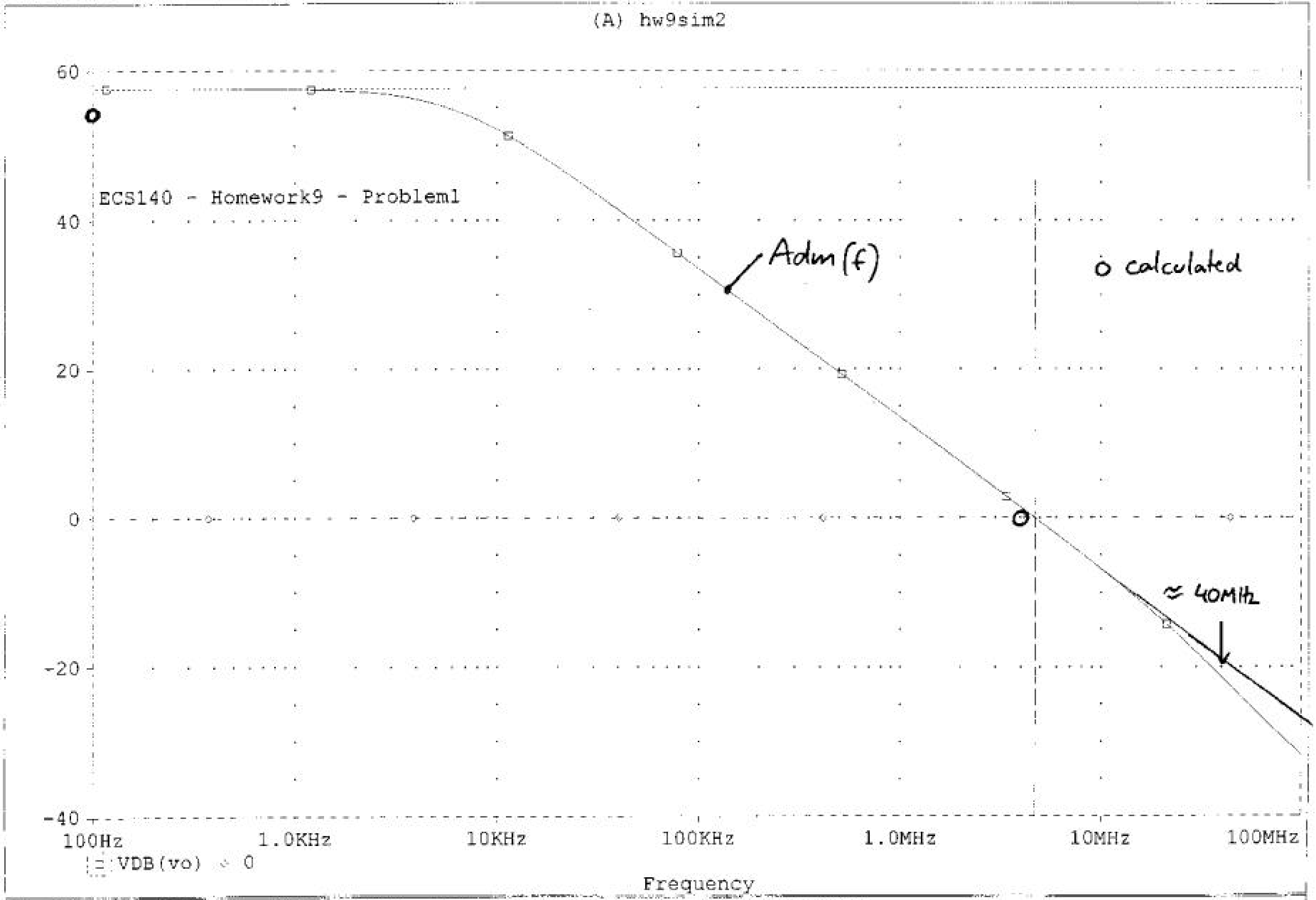
g) → see attached plots. (used $V_{icm} = 0V$)

	CALCULATED:	SIMULATED:	(ERROR)
A_{dm0}	500 ≙ 54dB	57dB ≙ 707	-30%
f_u	4MHz	4.7MHz	-15%
f_{p2}	33MHz	≈ 40MHz	

→ reasonable agreement, discrepancies due to neglecting λ in the hand analysis

* U:\Ee140\spice\hw9sim2.sch

Date/Time run: 10/21/99 18:51:31 Temperature: 27.0



A1:(100.000,57.627) A2:(4.7127M,-13.010m) DIFF(A):(-4.7126M,57.640)

Date: October 21, 1999 Page 1 Time: 18:53:45

5/5