EE140 HW8

(1) $I_s = 10^{-15} A$ $\quad I_D = 10^{-5} A$

$n = 144$

a) $V_{D1} = \frac{kT}{q} \ln\left(\frac{I_D}{I_S}\right) = \frac{kT}{q} \ln(10^{10}) \approx 600mV$

b) $V_{D2} = \frac{kT}{q} \ln\left(\frac{I_D}{nI_S}\right) = \frac{kT}{q}\left(\ln(10^{10}) - \ln(144)\right) \approx 470mV$

c) $\Delta V_D = \frac{kT}{q} \cdot \ln(n) \approx \frac{5kT}{q}$

T	ΔV_D
200K	86mV
300K	130mV
400K	170mV

#1) 10 pts
a) 1 pt
b) 1 pt
c) 3 pts - 1 per temperature
d) 1 pt
e) 3 pts - 1 for each curve (-1 for unlabeled axis)
f) 1 pt for curves shift up, but difference does not change

d)

$V_{D2} = V_{D1} - \Delta V_D$

$-1.5 mV/K \qquad \ln(n) \cdot \frac{k}{q} \approx .43 mV/K$

so tempco of V_{D2} is $-1.5 mV/K - .43 mV/K$

$\approx -1.93 mV/K$

(2) a) $\frac{\Delta V_D}{R1} = 10uA$

$R_1 = \frac{\Delta V_D}{10uA} = \frac{130mV}{10uA} = 13\ k\Omega$

b)

T	ΔV_D	I
200k	86mV	6.6uA
400k	170mV	13uA

c) $V_{R2} = 2\Delta V_D$

T	V_{R2}
200k	172mV
300k	260mV
400k	340mV

#2) 10 pts
a) 1 pt
b) 2 pts, 1 for values at each temperature
c) 3 pts - 1 for VR2 at each temperature
d) 2 pts for adding line to plot from #1
e) 2 pts - 1 for temp coefficient, one for giving a fix

d) $V_{ref} = V_{D1} + \frac{R_2}{R_1} \ln(n) V_T$

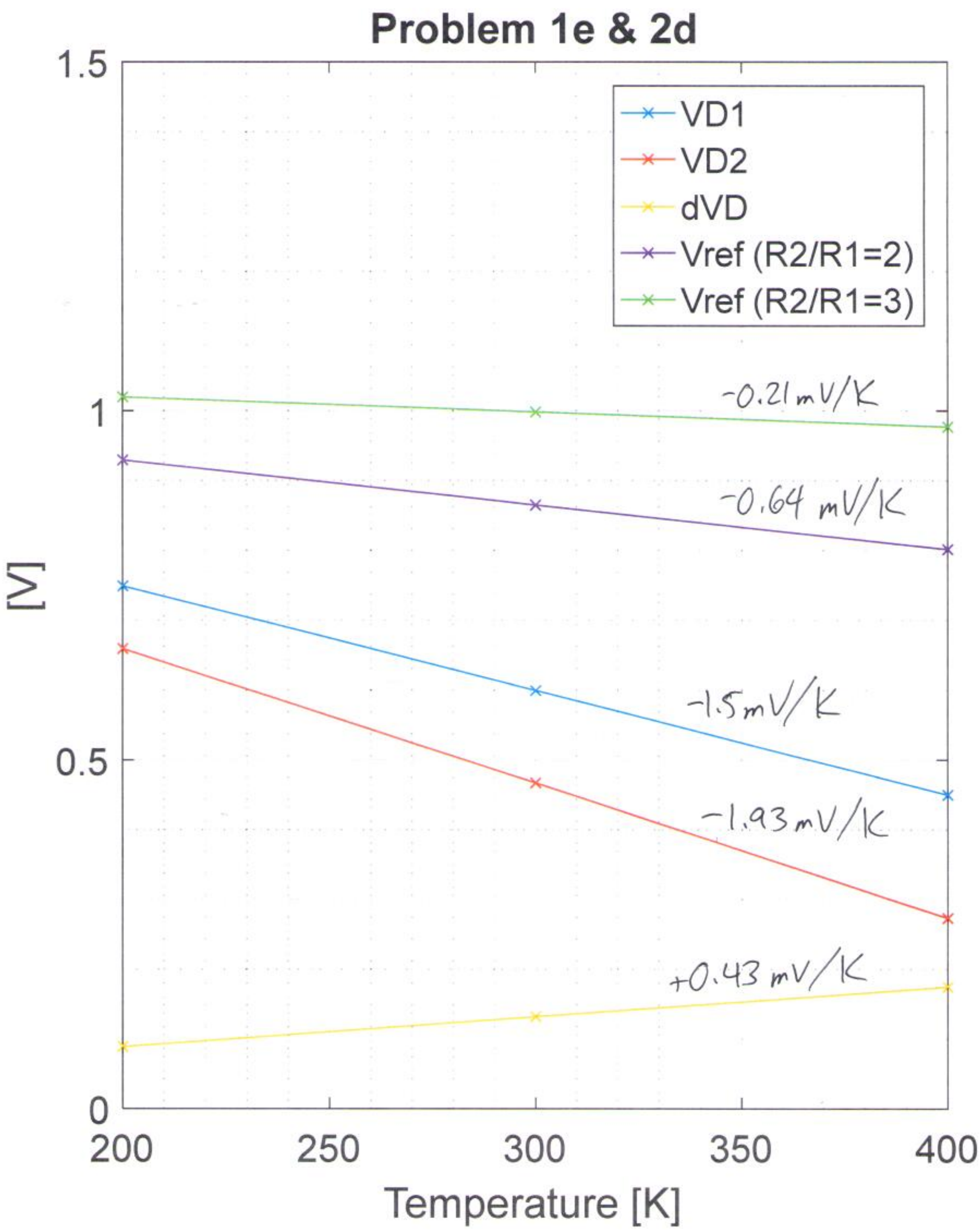
T	Vref
200K	923mV
300K	859mV
400K	795mV

(see prev page)

slope = $-.64 \frac{mV}{K}$

e) Fix it by increasing R_2/R_1 to 3.

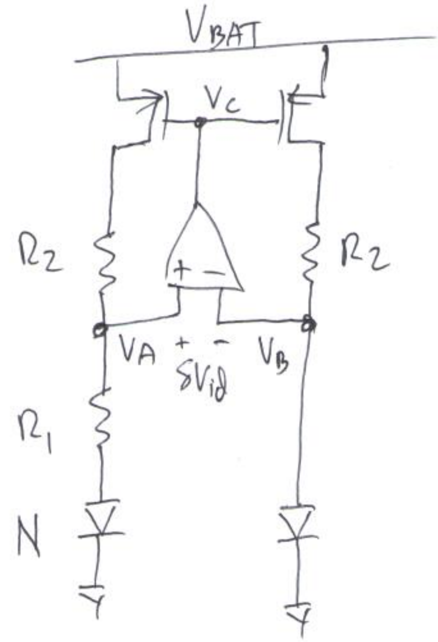
Tempco is $-0.64 \frac{mV}{K}$ (Need to add $1.5 \times .43\ mV/K$)



f) If Id goes up by 2x, both Vd1 and Vd2 shift up by VT * ln(2)

The difference between Vd1 and Vd2 DOES NOT CHANGE! It is constant regardless of the current.

(3)



#3) 8 pts
a) 3 pts for writing an expression for differential gain
b) 3 pts - 1 each for estimating pole locations at A,B,C
c) 2 pts for some discussion of stability and compensation
(240 only)
#4) 4 pts for some discussion of stability

a) Apply δV_{id}

$$\delta V_A = A_v \cdot \delta V_{id} \cdot g_m \cdot (R_1 + R_D) \qquad \left(R_D = \frac{V_{th}}{I}\right)$$

$$\delta V_B = A_v \cdot \delta V_{id} \cdot g_m \cdot R_D$$

Assuming in both cases that $R_2 + r_o$ is very large.

The differential output is $\delta V_A - \delta V_B$:

$$\frac{\delta V_A - \delta V_B}{\delta V_{id}} = A_v \cdot g_m \cdot R_1$$

but we know $I \cdot R_1 = \Delta V_{BE} = \ln(n) V_{th}$

so $R_1 = \dfrac{\ln(n) V_{th}}{I} = \dfrac{\ln(n) \cdot 2 V_{th}}{g_m \cdot V_{ov}} \qquad \left(g_m = \dfrac{2 I_D}{V_{ov}}\right)$

$$\frac{\delta V_A - \delta V_B}{\delta V_{id}} = A_v \cdot \cancel{g_m} \cdot \frac{\ln(n) \cdot 2V_{th}}{\cancel{g_m} \cdot V_{ov}} = A_v \cdot \frac{2\ln(n) \cdot V_{th}}{V_{ov}}$$

b) Poles :

@ V_C

$$\frac{1}{R_{out,amp} \cdot (2C_{gs} + A_{v,PMOS} \cdot C_{gd} \cdot 2)}$$

$A_{v,PMOS} = (g_m \times r_o // R_2 + R_D)$

@ V_A

$$\frac{1}{(R_2 + r_o) // (R_1 + R_D) \cdot C_{in,amp}}$$

@ V_B

$$\frac{1}{(R_2 + r_o) // (\cancel{R_1} + R_D) \cdot C_{in,amp}}$$

Zeros : $\frac{g_{m,PMOS}}{C_{gd,PMOS}}$ (Also there is the diff pair current mirror pole/zero doublet)

c) Yes, depending on the pole/zero locations and resulting phase margin.

Can compensate by adding cap at node C, or across nodes A and C.