University of Toronto

Term Test 1

Date - Oct 12, 2012 (3:15pm to 4:45pm)

Duration: 1.5 hrs

ECE331 — Analog Electronics
Lecturer - D. Johns

ANSWER QUESTIONS ON THESE SHEETS **USING BACKS IF NECESSARY**

1. Equation sheet is on last page of test.
2. Unless otherwise stated, use transistor parameters on equation sheet.
3. Non-programmable calculator allowed; No other aids allowed
4. Grading indicated by [ ]. Attempt all questions since a blank answer will certainly get 0.

Question	Mark
1	
2	
3	
4	
5	
6	
Total	

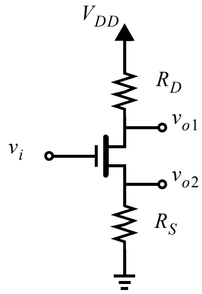
(max grade = 36)

Last Name: ______________________

First Name: ______________________

Student #: ______________________

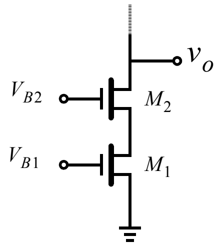
[6] Question 1: For the nmos circuit below, draw the small-signal T-model and derive expressions for v_{o1}/v_i and v_{o2}/v_i in terms of R_D, R_S and $r_s = 1/g_m$. Assume $\lambda = 0$.



$$\frac{v_{o1}}{v_i} =$$

$$\frac{v_{o2}}{v_i} =$$

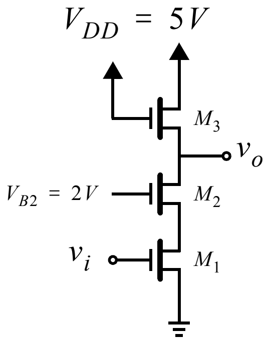
[6] Question 2: Consider the current mirrow below. If the current mirror is designed for a current of $20\mu A$, find the voltages V_{B1} and V_{B2} such that v_O can go as low as possible while the transistors remain in the active region. Find the minimum output voltage, v_{O_min}?



all $L = 0.5\mu m$
$W_1 = 2\mu m$
$W_2 = 1\mu m$
$I_D = 20\mu A$

V_{B1} =
V_{B2} =
v_{O_min} =

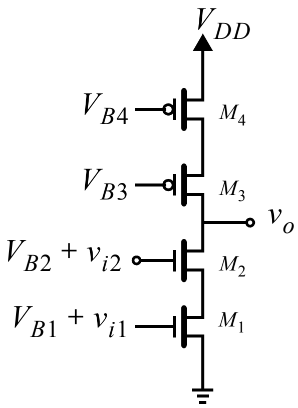
[6] Question 3: Find the small-signal gain, v_o/v_i and output resistance R_o. (ignore r_o when finding i_{sc} but include r_o when finding R_o).



all $L = 0.5\mu m$
$W_1 = W_2 = 20\mu m$
$W_3 = 4\mu m$
v_i bias voltage is 1V

$\frac{v_o}{v_i} =$
$R_o =$

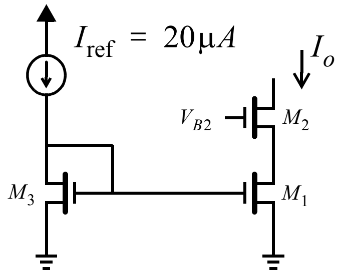
[6] Question 4: For the circuit below, all $V_{ov} = 200mV$ and all $I_D = 50\mu A$. The designer is concerned about noise on V_{B1} and V_{B2} bias lines. Find the gains v_o/v_{i1} and v_o/v_{i2}. (Include r_{o1} when finding i_{SC} for v_o/v_{i2} otherwise ignore r_o when finding i_{SC})



all $L = 0.5\mu m$

$\frac{v_o}{v_{i1}} =$
$\frac{v_o}{v_{i2}} =$

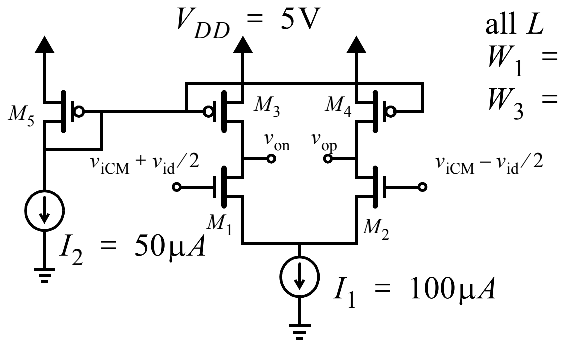
[6] Question 5: Consider the current mirror shown below. Using small-signal analysis, estimate the change in I_o when there is a V_{tn} mismatch of 5mV between M_1 and M_3. Ignore r_o.



all $L = 0.5\mu m$
$W_1 = W_2 = W_3 = 2\mu m$

$\Delta I_o =$

[6] Question 6: Consider the circuit below where $v_{iCM} = 2V$.



all $L = 0.5\mu m$
$W_1 = W_2 = 5\mu m$
$W_3 = W_4 = W_5 = 20\mu m$

a) What is the max and min for v_{op}?

$v_{op\_min} =$
$v_{op\_max} =$

b) Find the gain, v_o/v_{id}.

$v_o/v_{id} =$

Last Name: ________________

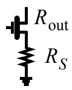
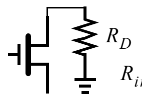
ECE331 **Analog Electronics** **Equation Sheet**

Constants: $k = 1.38 \times 10^{-23}\ \mathrm{JK}^{-1}$; $q = 1.602 \times 10^{-19}$ C ; $V_T = kT/q \approx 26\,\mathrm{mV}$ at 300 °K ;
$\varepsilon_0 = 8.854 \times 10^{-12}$ F/m ; $k_{\mathrm{ox}} = 3.9$; $C_{\mathrm{ox}} = (k_{\mathrm{ox}}\varepsilon_0)/t_{\mathrm{ox}}$

NMOS: $k_n = \mu_n C_{\mathrm{ox}}(W/L)$; $V_{tn} > 0$; $v_{\mathrm{DS}} \ge 0$; $v_{ov} = v_{GS} - V_{tn}$
(triode) $v_{\mathrm{DS}} \le v_{ov}$ (or $v_D < v_G - V_{tn}$) ; $i_D = k_n((v_{ov})v_{\mathrm{DS}} - (v_{\mathrm{DS}}^2/2))$
(active) $v_{\mathrm{DS}} \ge v_{ov}$; $i_D = 0.5k_n v_{ov}^2(1 + \lambda v_{DS})$; $g_m = k_n V_{ov} = 2I_D/V_{ov} = \sqrt{2k_n I_D}$; $r_s = 1/g_m$; $r_o = L/(|\lambda'|I_D)$

PMOS: $k_p = \mu_p C_{\mathrm{ox}}(W/L)$; $V_{tp} < 0$; $v_{SD} \ge 0$; $v_{ov} = v_{SG} - |V_{tp}|$
(triode) $v_{SD} \le v_{ov}$ (or $(v_D > v_G + |V_{tp}|)$) ; $i_D = k_p((v_{ov})v_{SD} - (v_{SD}^2/2))$
(active) $v_{\mathrm{DS}} \ge v_{ov}$; $i_D = 0.5k_p v_{ov}^2(1 + |\lambda| v_{SD})$; $g_m = k_p V_{ov} = 2I_D/V_{ov} = \sqrt{2k_p I_D}$; $r_s = 1/g_m$; $r_o = L/(|\lambda'|I_D)$

BJT**:** (active) $i_C = I_S e^{(v_{BE}/V_T)}(1 + (v_{CE}/V_A))$; $g_m = \alpha/r_e = I_C/V_T$; $r_\pi = \beta/g_m$; $r_o = |V_A|/I_C$
$i_C = \beta i_B$; $i_E = (\beta + 1)i_B$; $\alpha = \beta/(\beta + 1)$; $i_C = \alpha i_E$; $R_b = (\beta + 1)(r_e + R_E)$; $R_e = (R_B + r_\pi)/(\beta + 1)$

Cascode:  $R_{\mathrm{out}} = R_S + r_o + g_m r_o R_S \approx (1 + g_m R_S)r_o$  $R_{in} = (R_D + r_o)/(1 + g_m r_o) \approx R_D/(g_m r_o) + 1/g_m$

Diff Pair: $A_d = g_m R_D$; $A_{CM} = -(R_D/(2R_{SS}))((\Delta R_D)/R_D)$; $A_{CM} = -(R_D/(2R_{SS}))((\Delta g_m)/g_m)$
$V_{os} = \Delta V_t$; $V_{os} = (V_{ov}/2)((\Delta R_D)/R_D)$; $V_{os} = (V_{ov}/2)((\Delta(W/L))/(W/L))$

MOS Transistor; CMOS basic parameters. Channel length = $0.18\mu m$

	V_t (V)	μC_{ox} $(\mu A/V^2)$	λ' $(\mu\mathrm{m/V})$	C_{ox} $(\mathrm{fF}/\mu\mathrm{m}^2)$	t_{ox} $(n\mathrm{m})$
NMOS	0.4	240	0.05	8.5	4
PMOS	-0.4	60	-0.05	8.5	4