Department of EEE, BITS PILANI K. K. BIRLA GOA CAMPUS

End-Semester Question Paper – Analog IC Design (MEL G 632)

Date: 15-05-2023 **Time: 14:00 hours to 17:00 hours**

Duration: 180 minutes **Closed Book** **Full-Marks: 35**

Attempt All Questions. Please use the Table given at the end to select appropriate values wherever they are not given in the question.

1. **In the circuit given in Fig. 1, $\left(\frac{W}{L}\right)_{1-3} = \frac{50\mu m}{0.5\mu m}$, $I_{D1} = |I_{D2}| = |I_{D3}| = 0.5mA$ and $R_{S1} = R_F = R_{D2} = 3\ k\Omega$. Ignore L-diffusion, body effect; assume the devices are in saturation.**

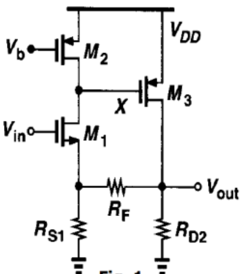

Fig. 1

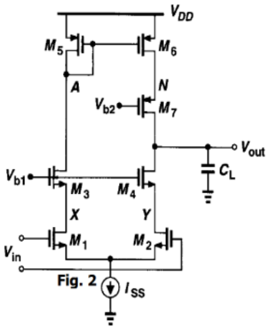

Fig. 2

(a) Determine the input bias voltage (V_{in}) required to establish the above currents.
(b) Calculate the closed loop voltage gain and output impedance.

2 + 4 + 4 = 10-marks

2. **For the telescopic cascode amplifier of Fig. 2, the parameters are given below. Determine the poles (use Miller's theorem, direct analyses not required). If dominant pole compensation is to be done, which node would be selected for putting additional capacapitor? What would be the ϕ-margin after compensation? Given: $\left(\frac{W}{L}\right)_{1-4} = \frac{5\mu m}{0.5\mu m}, \left(\frac{W}{L}\right)_{5-7} = \frac{7.5\mu m}{0.5\mu m}, C_L = 50\ pF, C_{GS5,6} = 100\ pF = 2C_{DB5,6} = 2C_{GD5,6}, C_{DB3,4} = C_{GD3,4} = 30\ pF, I_{D5,6} = 0.5\ mA$ and the total capacitance at node N $= 100\ pF$ and X(Y) $= 150\ pF$. Ignore L-diffusion, body effect and assume small-signal open loop output impedance at no load to be very large.**

4×2+1+1 = 10-marks

3. **Identify the feedback type for Fig. 3 and Fig. 4 and calculate the closed loop input impedance of each. Ignore loading, L-diffusion and channel length modulation but include body effect (g_{mb}=0.1g_m) transconductance. Given $\left(\frac{W}{L}\right)_{1-2} = \frac{50\mu m}{0.5\mu m}$, $C_1 = C_2 = 5\ pF$, $R_D = 5\ k\Omega$ and $I_{D1} = 0.5\ mA$.**

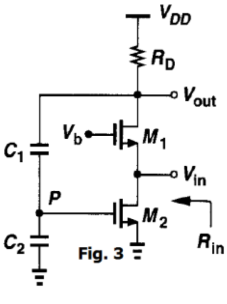

Fig. 3

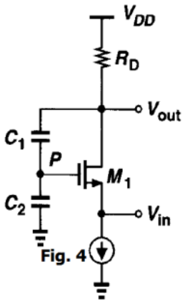

Fig. 4

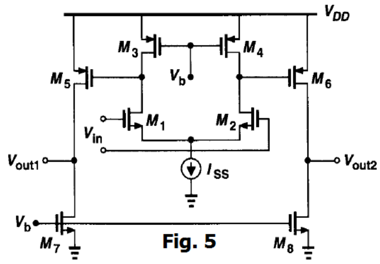

Fig. 5

1+4+1+4= 10-marks

4. In the circuit given in Fig. 5, $\left(\frac{W}{L}\right)_{1-2,7-8} = \frac{50\mu m}{0.5\mu m}$ and $\left(\frac{W}{L}\right)_{3-6} = \frac{75\mu m}{0.5\mu m}$, $I_{SS} = 1\,mA = I_{D7} + I_{D8}$. Estimate the voltage gain and the output swing. Assume the circuit is symmetrical; the transistors are in saturation and ignore body effect.

3+2= 5-marks

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[i]**Table of Values**

Parameters	V_{Th}(V)	γ ($\sqrt{V}$)	ϕ_f(V)	L_D (m)	λ(V^{-1}) for L_{Geo}=0.5µm	$k'_{n/p} = \mu_{n/p}C_{OX}$(A/V^2)
NMOS	0.7	0.5	0.9	0.08×10^{-6}	0.1	134.26×10^{-6}
PMOS	-0.8	0.4	0.8	0.09×10^{-6}	0.2	38.36×10^{-6}
Common	$n_i = 1.45 \times 10^{10} cm^{-3}$, q= $1.6\times 10^{-19}C$; k = $1.38\times 10^{-23}\frac{J}{K}$; V_{DD}= V_{Ck}= 3.0V; V_{SS}= 0 V; β_{NPN}=150, β_{PNP}=100, Room Temperature= 27^0C; ε_{Si}=11.68; ε_{SiO_2}=3.6; ε_0= $8.85 \times 10^{-12}\frac{F}{m}$; $C_{GDO_{NMOS}} = 0.4 \times 10^{-9}\frac{F}{m}$; C_{ox}=6.9 $fF/\mu m^2$ for t_{ox}= 50$\dot{A}$					

Table of Equations (*You might have seen in a distant galaxy....)*

1.	$I_D = \frac{1}{2}\mu_{n/p}C_{OX}\left(\frac{W}{L}\right)(V_{GS} - V_T)^2$; $I_D = \frac{1}{2}\mu_{n/p}C_{OX}\left(\frac{W}{L}\right)(V_{GS} - V_T)^2(1 + \lambda V_{DS})$ when channel length is included
2.	$\phi_0 = \frac{kT}{q}\ln\left(\frac{N_D N_A}{n_i^2}\right)$
3.	$Q_{B0} = -\left(1 - \frac{\Delta L_S + \Delta L_D}{2L}\right)\sqrt{2q\epsilon_{Si}N_A\|2\Phi_F\|}$
4.	$C_{j0} = \sqrt{\frac{q\epsilon_{Si}}{2}\left(\frac{N_D N_A}{N_D + N_A}\right)\frac{1}{\Phi_0}}$
5.	$\Delta V_{T0} = \frac{1}{C_{ox}}\sqrt{2q\xi_{Si}N_A\|2\Phi_F\|}\cdot\frac{x_j}{2L}\cdot\left[\left(\sqrt{1+\frac{2x_{dS}}{x_j}} - 1\right) + \left(\sqrt{1+\frac{2x_{dD}}{x_j}} - 1\right)\right]$
6.	$x_d = \sqrt{\frac{q\epsilon_{Si}}{2}\left(\frac{N_D N_A}{N_D + N_A}\right)(\Phi_0 - V)}$