# 2015 Analog IC: Final Examination (110%)

1. An amplifier with feedback capacitor $C_F$, open-loop gain $-A$, and equivalent circuit as shown in Fig. 1. Find $Z_1$ and $Z_2$ using Miller effect. (5%)

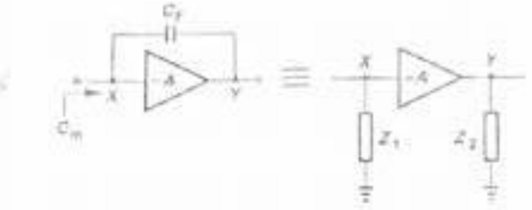


Fig. 1

2. Fig. 2 shows a common gate amplifier with $C_D = 20fF$, $C_S = 20fF$, $C_L = 100fF$, $g_{mb} = 0$, $r_o = \infty$, $g_m = 1mA/V$, $R_S = 10k\Omega$, and $R_D = 100k\Omega$. **(5%)**
   (a) Find the input and output impedances. (2.5%)
   (b) Find the correlated input pole $\omega_{in}$ and output pole $\omega_{out}$. (2.5%)

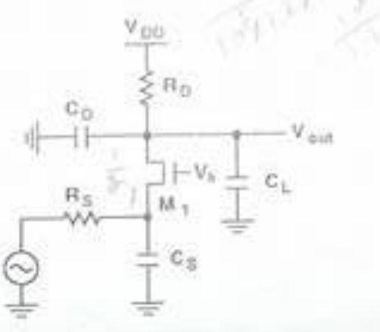


Fig. 2

3. A two-stage Op Amp in Fig. 3 has $A_{v1} = 20$, $A_{v2} = 40$. The output referred noise of $A1 = 2\times10^{-12}$ $V^2/Hz$ and $A2 = 4\times10^{-12}$ $V^2/Hz$. **(5%)**
   (a) Find the output referred noise of amplifier A. (2.5%)
   (b) Find the "**best**" input referred noise with same total gain A = 800. (2.5%)

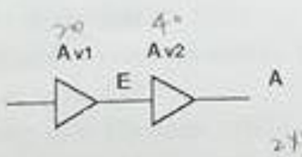


Fig. 3

4. A common source amplifier is shown in Fig. 4. The thermal noise and flicker noise of $M_1$ are $4kT g_m(\frac{2}{3})$ and $\frac{K}{C_{ox}WL}\cdot\frac{1}{f}$, the thermal noise of $R_D$ is $4KTR_D$. **(5%)**
   (a) Derive the output referred noise. (2.5%)
   (b) Derive the input referred noise. (2.5%)

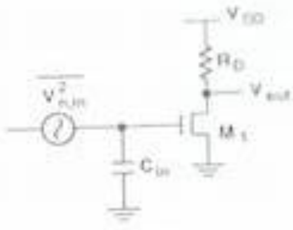


Fig. 4

5. An amplifier with a DC gain = 60dB and two poles at 1Mhz and 100Mhz. (10%)
   (a) Sketch the Bode plot with amplitude and phase. (2.5%)
   (b) Determine and explain the system is stable or not (Phase margin > 45°). (2.5%)
   (c) Do the frequency compensation to get a phase margin = 45° and explain the new locations of poles. (5%)

6. Fig. 6 shows a differential pair with $C_E = 20fF$, $C_L = 100fF$, $g_{mb} = 0$, $r_o = 100k\Omega$, $g_m = 1mA/V$, $|V_{ov}| = 0.2V$, $|V_{th}| = 0.6V$. **(10%)**
   (a) Find the minimum input DC bias voltage with $V(I_{SS}) = 0.3V$. (2.5%)
   (b) Find the voltage gain $V_{out}/V_{in}$. (2.5%)
   (c) Find the dominant pole $\omega_{p1}$. (2.5%)
   (d) Find the value of zero $\omega_z$. (2.5%)

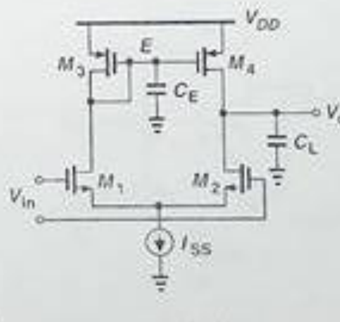


Fig. 6

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7. A general block diagram of feedback system is shown in Fig. 7. Assume $A(s) = A_0/[1+(s/\omega_0)]$, answer the following questions. **(10%)**
   (a) State the oscillation condition. (Barkhausen's Criteria). (2%)
   (b) Find the equation of closed loop gain. (2%)
   (c) Explain the ***bandwidth modification*** of closed- loop system. (2%)
   (d) List down 4 types of feedback topology. (2%)
   (e) Explain the impedance modification of the 4 feedback structures in terms of equations of $R_{in,closed}/R_{in,open}$ and $R_{o,closed}/R_{o,open}$. (2%)

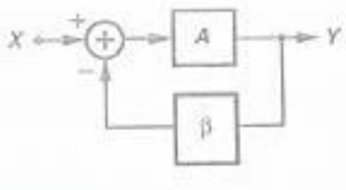


Fig. 7

8. A closed-loop amplifier is shown in Fig. 8 with $R1 = 400K\Omega$ and $R2 = 100\ K\Omega$. **(5%)**
   (a) With the open loop gain A = 100, find the closed-loop gain. (2.5%)
   (b) Find the requirement of A to get an error of closed-loop gain smaller than 1% of ideal one ($A = \infty$). (2.5%)

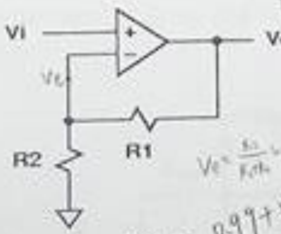


Fig. 8

9. Explain the definitions and purposes of the following terminologies. **(10%)**
   (a) Miller compensation. (2%)
   (b) Noise power spectrum density. (2%)
   (c) Flicker noise. (2%)
   (d) Slewing in an Op Amp. (2%)
   (e) Power-supply rejection ratio (PSRR). (2%)

10. Fig. 10 shows a closed-loop amplifier with $r_o = 100k\Omega$ and $g_m = 1mA/V$. **(10%)**
   (c) Find the feedback factor. (2%)
   (d) Find the open-loop gain with loading effect. (4%)
   (e) Find closed-loop gain $V_{out}/V_{in}$. (2%)
   (f) Find closed-loop output impedance. (2%)

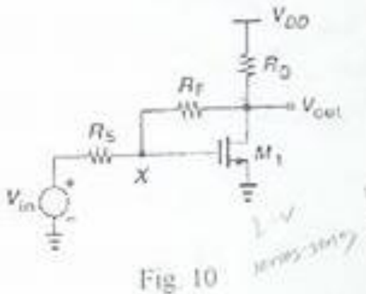


Fig. 10

11. An impedance boosting circuit is as shown in Fig. 11. Find the $R_{out}$ in term of $r_{o[n]}$ and $g_{m[n]}$. **(5%)**

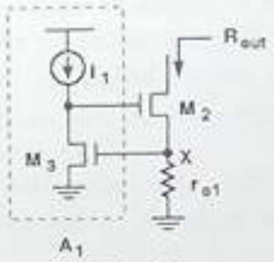


Fig. 11

12. A unity-gain buffer is shown in Fig. 12 with $|V_{gs[n]}| = 0.8V$, $|V_{th[n]}| = 0.6V$, and $V_{DD} = 2.5V$, find the available output range. **(5%)**

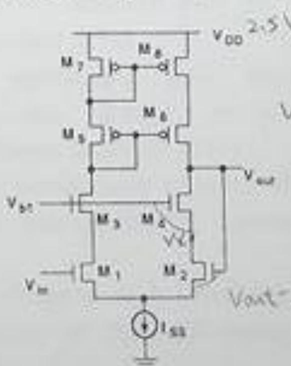


Fig. 12

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13. Find slew rate of the following Op Amps. **(5%)**
   (a) The differential-to-single-ended amplifier with capacitive feedback. (2.5%)
   (b) 2-stage OP Amp with capacitor $C_C$. (2.5%)

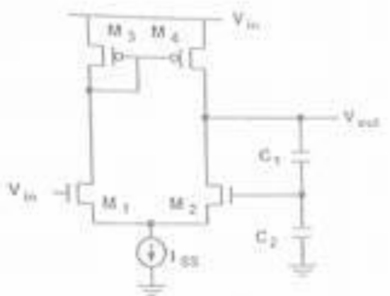

Fig. 13(a)

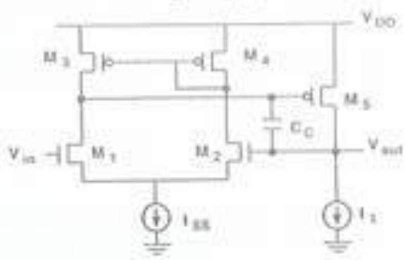

Fig. 13(b)

14. In Fig. 14, $g_m$ = 1mA/V, $r_o$ = 100KΩ, $C_{GD}$ = $C_{GS}$ = 10fF, $C_{DB}$ = $C_{SB}$ = 5fF, $R_S$ = 10kΩ, and $R_D$ = 100kΩ. **(5%)**
   (a) Use Miller effect to find the equivalent $C_{in}$ at node X and $C_{out}$ at node $V_{out}$. (2.5%)
   (b) Find the input pole $\omega_{in}$ and output pole $\omega_{out}$. (2.5%)

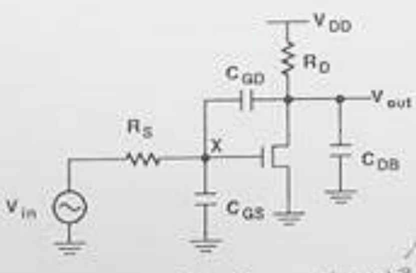

Fig. 14

15. Fig. 15 shows a common-source amplifier with $g_{m1}$ = $g_{m2}$ = 1mA/V, $r_{o1}$ = $r_{o2}$ = 100kΩ, $V_b$ = 2.5V, $V_{in}$ = 1V, $V_{DD}$ = 3.3V, $|V_{tn}|$ = $|V_{tp}|$ = 0.5V. **(5%)**
   (a) Find the available output swing. (2.5%)
   (b) Find the small-signal voltage gain $V_{out}/V_{in}$. (2.5%)

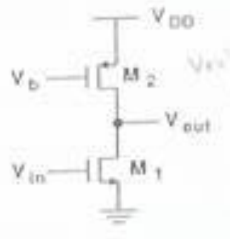

Fig. 15

16. Answer the following questions with TRUE or FALSE. **(10%)**
   (a) Flicker noise of MOS device and noise of resistor are all white noise. (1%)
   (b) Phase margin is defined of the phase shift distance to -180° at 0dB. (1%)
   (c) CMRR is defined by the ratio between $A_{DM}/A_{CM}$ and it will degrade at high frequency. (1%)
   (d) Left half plane zero will degrade the stability due to its negative phase shift. (1%)
   (e) Usually the noise types in a circuit are from device and environmental noise. (1%)
   (f) The linear response is degraded when Op Amp enters the slewing condition. (1%)
   (g) Oscillation happens only in closed-loop architecture. (1%)
   (h) The input/output port impedance of closed-loop system is increase by serial/serial feedback. (1%)
   (i) Noise performance is usual illustrated by power spectral density express in $V^2$/Hz. (1%)
   (j) The common-mode feedback circuit is necessary in fully-differential OP Amp. (1%)

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