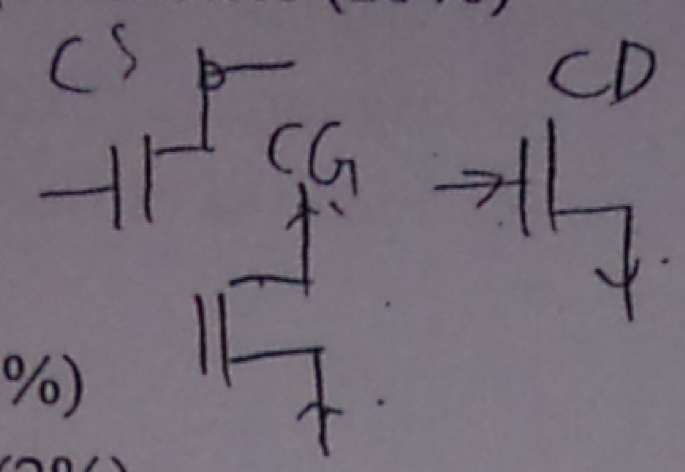
2012 Analog IC: Final Examination (130%)

1. Assume the 4 types of single stage amplifiers (CS, CG, and CD) use same MOS, bias at same current, having same R_{load}, C_{load}, and are driven by same source resistance R_s. Please make the ranking based on following parameters (10%)
   (a) DC voltage gain. (2%)
   (b) Input capacitance. (2%)
   (c) Output resistance. (2%)
   (d) Input pole frequency. (2%)
   (e) Output pole frequency. (2%)



2. A common source amplifier is shown in Fig. 2 with the MOSFET bias of g_m and $r_o = \infty$. (4%)
   (a) Use Miller effect to find the equivalent C_{in} at node X and C_{out} at node V_{out}. (2%)
   (b) Find the correlated input pole ω_{in} and output pole ω_{out}. (2%)

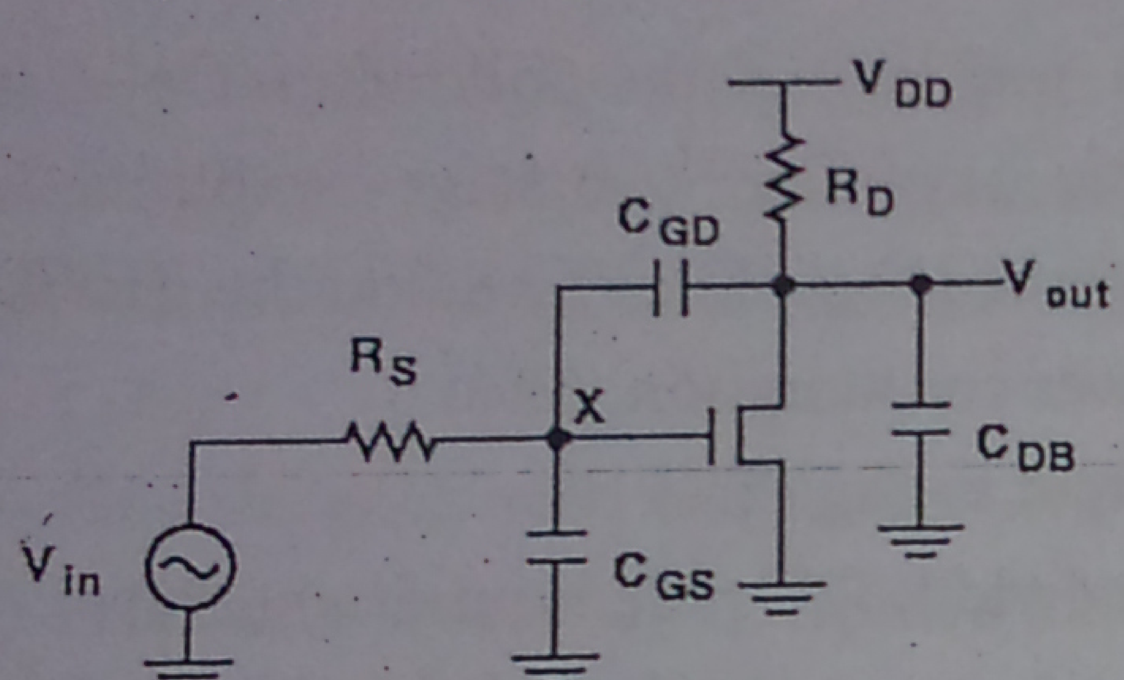


Fig. 2

3. A differential pair with capacitance loading is shown in Fig. 3 (6%)
   (a) Find the node of dominant pole and express it in terms of r_{ox} and C_x. (2%)
   (b) Find the node of second pole and express it in terms of g_{mx} and C_x. (2%)
   (c) Find the zero and express it in terms of g_{mx} and C_x. (2%)

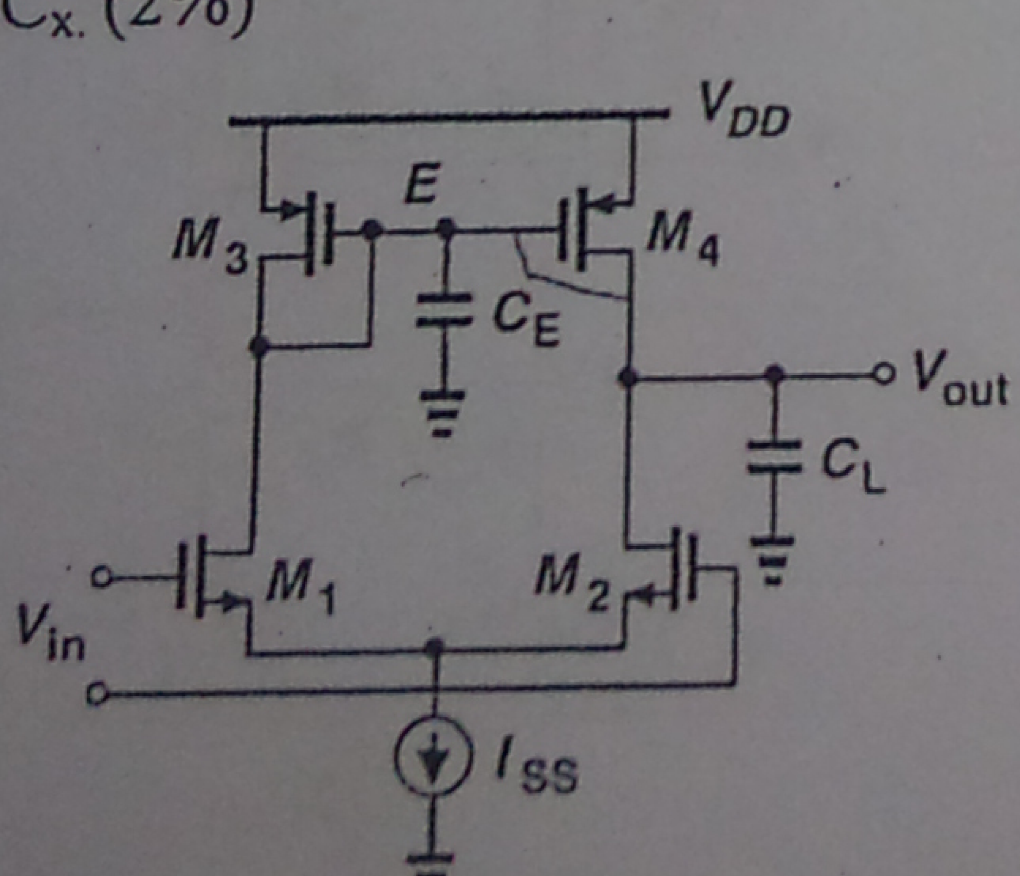


Fig. 3

4. Explain the following terminologies (10%)
   (a) Power Spectrum (Spectral) Density. (2%)
   (b) White Noise. (2%)
   (c) Corner Frequency. (2%)
   (d) 1/f Noise. (2%)
   (e) Input-referred noise. (2%)

5. A common source amplifier is shown in Fig. 5. The thermal noise of $R_D = 4kTR_D$. The thermal noise and flicker noise of M_1 are $\overline{I_n^2} = 4kTg_m(\frac{2}{3})$ and $\overline{V_n^2} = \frac{K}{C_{ox}WL} \cdot \frac{1}{f}$. (10%)
   (a) Derive the input referred noise $\overline{V_{n,in}^2}$ due to thermal noise. (5%)
   (b) Derive the input referred noise $\overline{V_{n,in}^2}$ due to flicker noise. (5%)

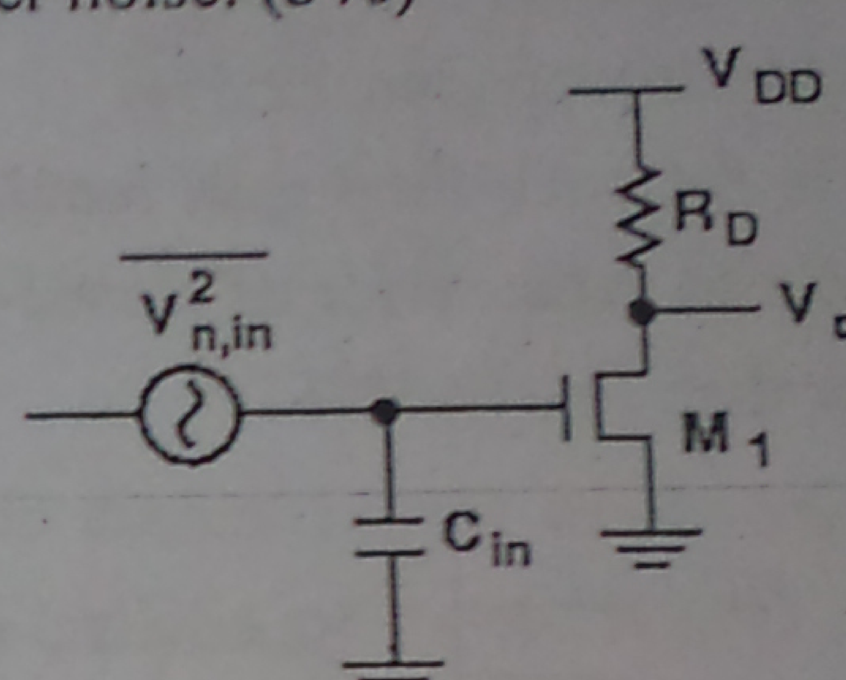


Fig. 5

6. Explain the definitions and purposes of the following terminologies. (10%)
   (a) Common mode feedback. (2%)
   (b) Frequency compensation. (2%)
   (c) Barkhausen's Criteria. (2%)
   (d) Slewing in an Op Amp. (2%)
   (e) Phase margin. (2%)

7. A general block diagram of feedback system is shown in Fig. 7. Assume the input and output resistances of feed-forward amplifier are R_{in} and R_{out}. (10%)
   (a) Find the loop gain. (2%)
   (b) Find the closed loop gain. (2%)
   (c) Find the input impedance of closed-loop amplifier. (2%)

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(d) Find the output impedance of closed-loop amplifier.. (2%)

(e) Explain *gain degeneration* of closed-loop system compared to open-loop. (2%)

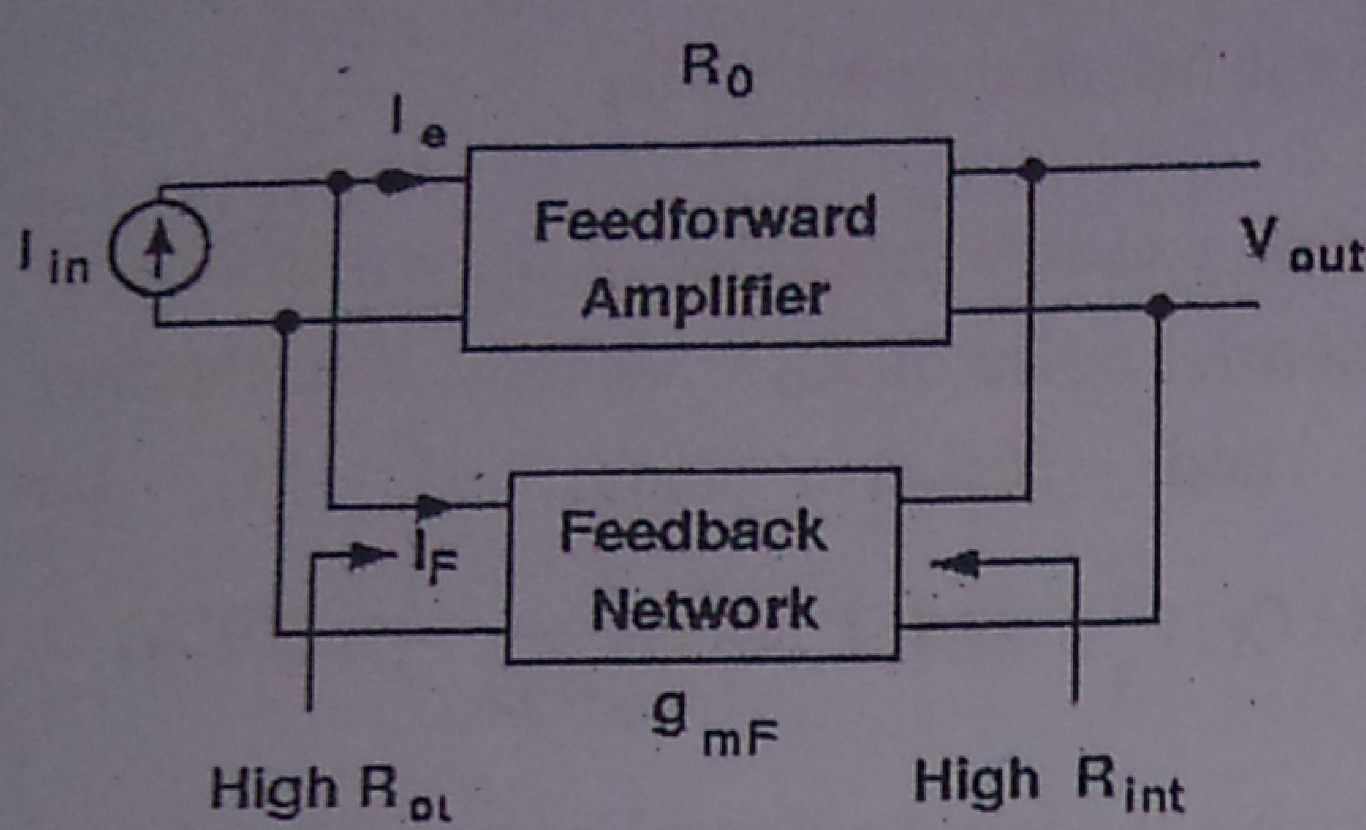

Fig. 7

8. A closed-loop amplifier is shown in ~~Fig. 9~~ Fig 8 with R1 = 900KΩ and R2 = 100 KΩ. (5%)

(a) With the gain of Op Amp = ∞, find the ideal closed-loop gain. (2.5%)

(b) What is the open-loop gain requirement of Op Amp to get an error of closed-loop gain smaller than 1%. (2.5%)

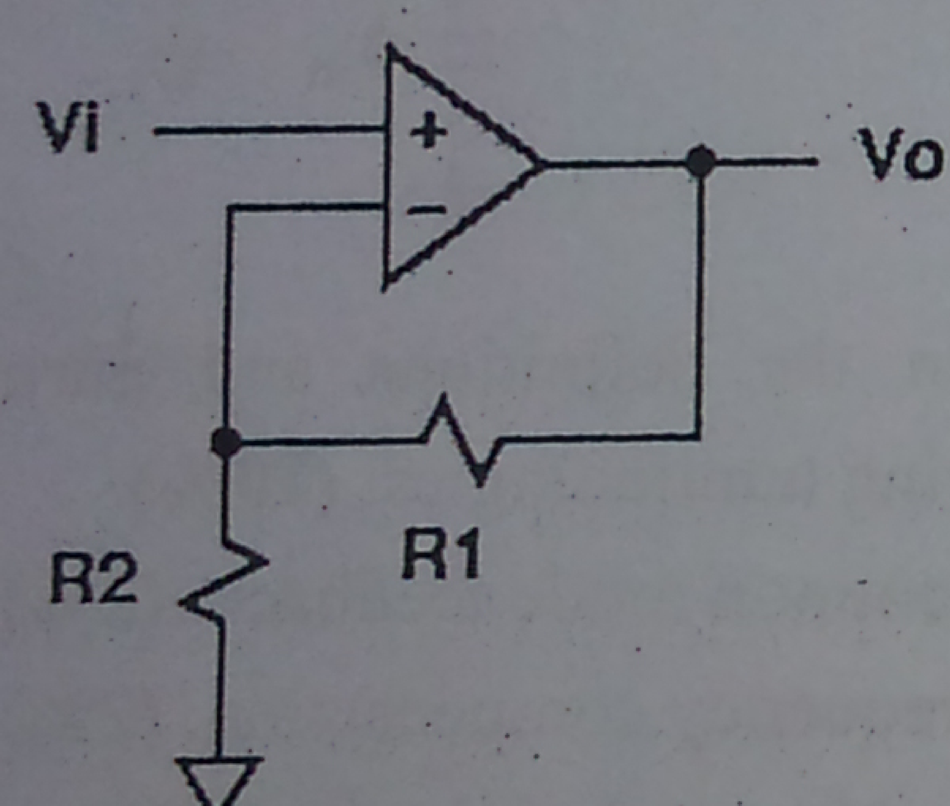

Fig. 8

9. An impedance boosting circuit is as shown in Fig. ~~10~~ 9. Find the R_{out} in term of r_{ox} and g_{mx}. (5%)

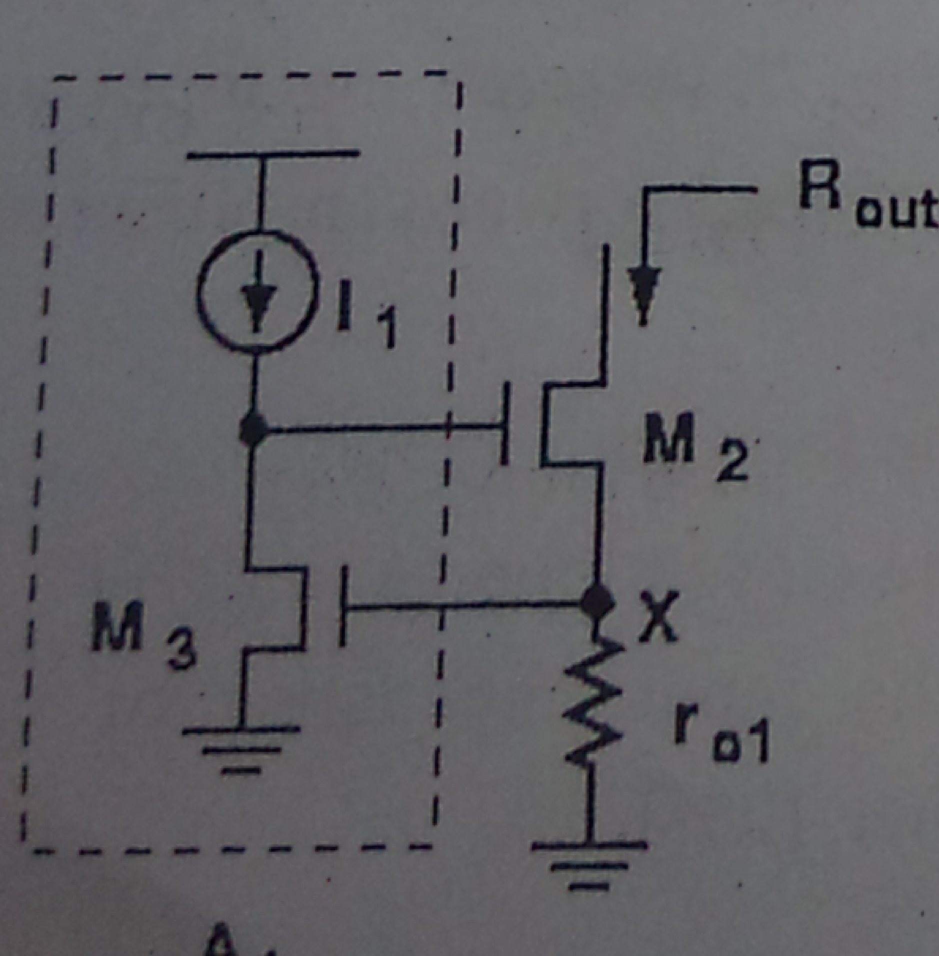

Fig. 9

10. A voltage-voltage feedback amplifier as shown in Fig. ~~11~~ 10 is biased with g_{m1} of M_1 and g_{m2} of M_2. (10%)

a ~~(c)~~ Find the feedback factor. (2%)

b ~~(d)~~ Find the open-loop gain with loading effect. (ignore r_o effect) (4%)

c ~~(e)~~ Find the closed-loop gain V_{out}/V_{in}. (4%)

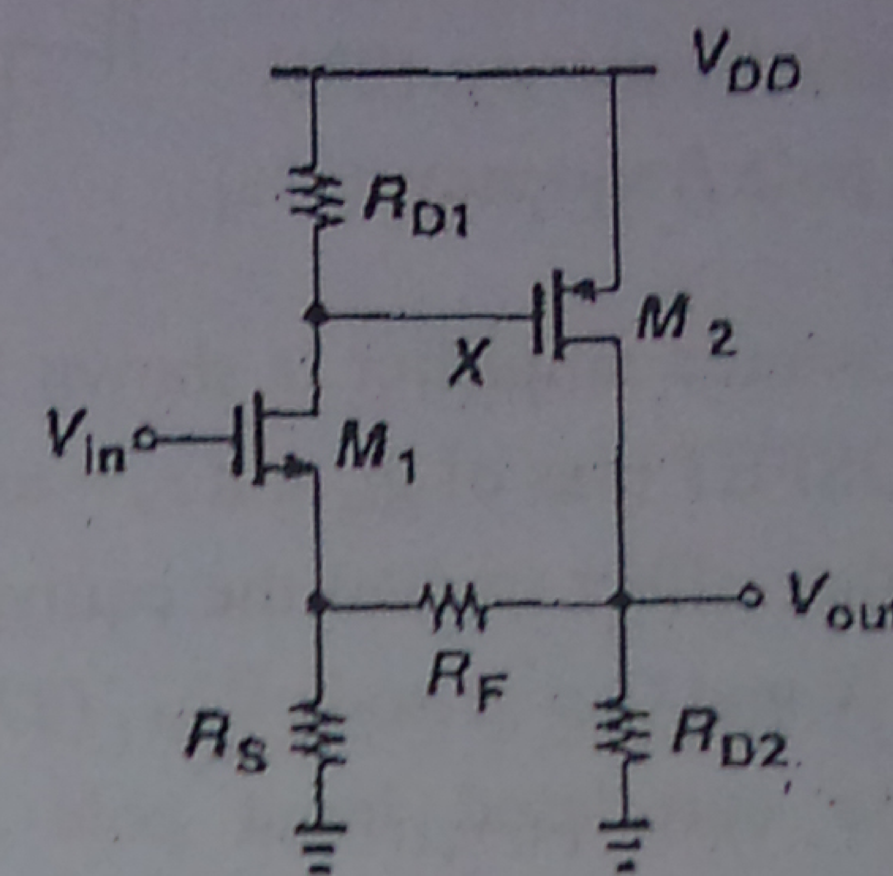

Fig. 10

11. Make a ranking of the following Op Amps: telescopic amplifier, two-stage amplifier, and folded-cascode amplifier based on the. (10%)

(a) Power consumption. (2%)

(b) Output swing (2%)

(c) Bandwidth (2nd pole locations) (2%)

(d) Sketch an example schematic of folded-cascode amp. (2%)

(e) Sketch an example schematic of gain-boosted telescopic amp. (2%)

12. Sketch a common-mode feedback circuit for the telescopic Op Amp is shown in Fig. 12. (5%)

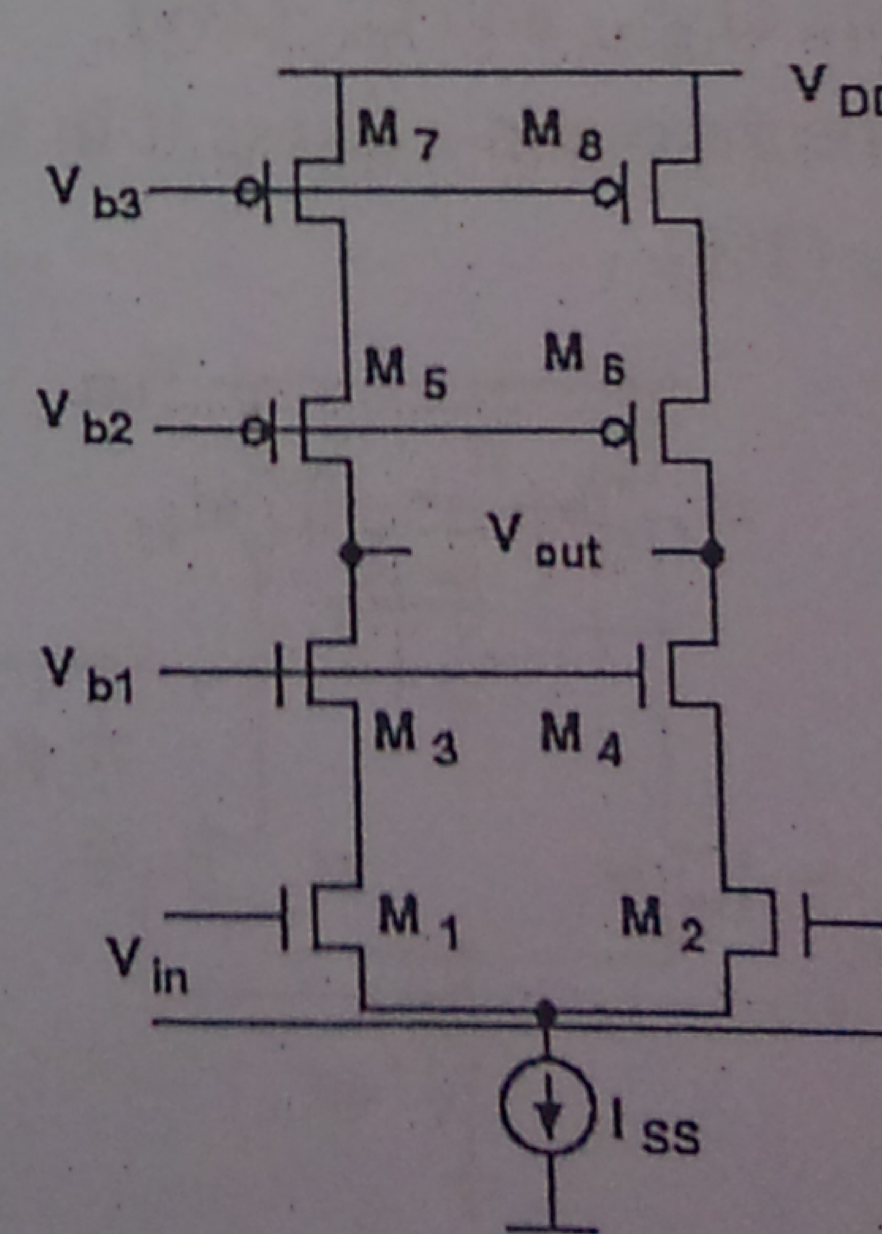

Fig. 12

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13. A unity-gain voltage buffer implemented by telescopic Op Amp with $V_{TH} = 0.5V$, $V_{GSx} = 0.7V$, and $V_{ISS} = 0.3V$ is shown in Fig. 13. (4%)
    (a) Find the minimum output voltage. (2%)
    (b) Find the maximum output voltage. (2%)

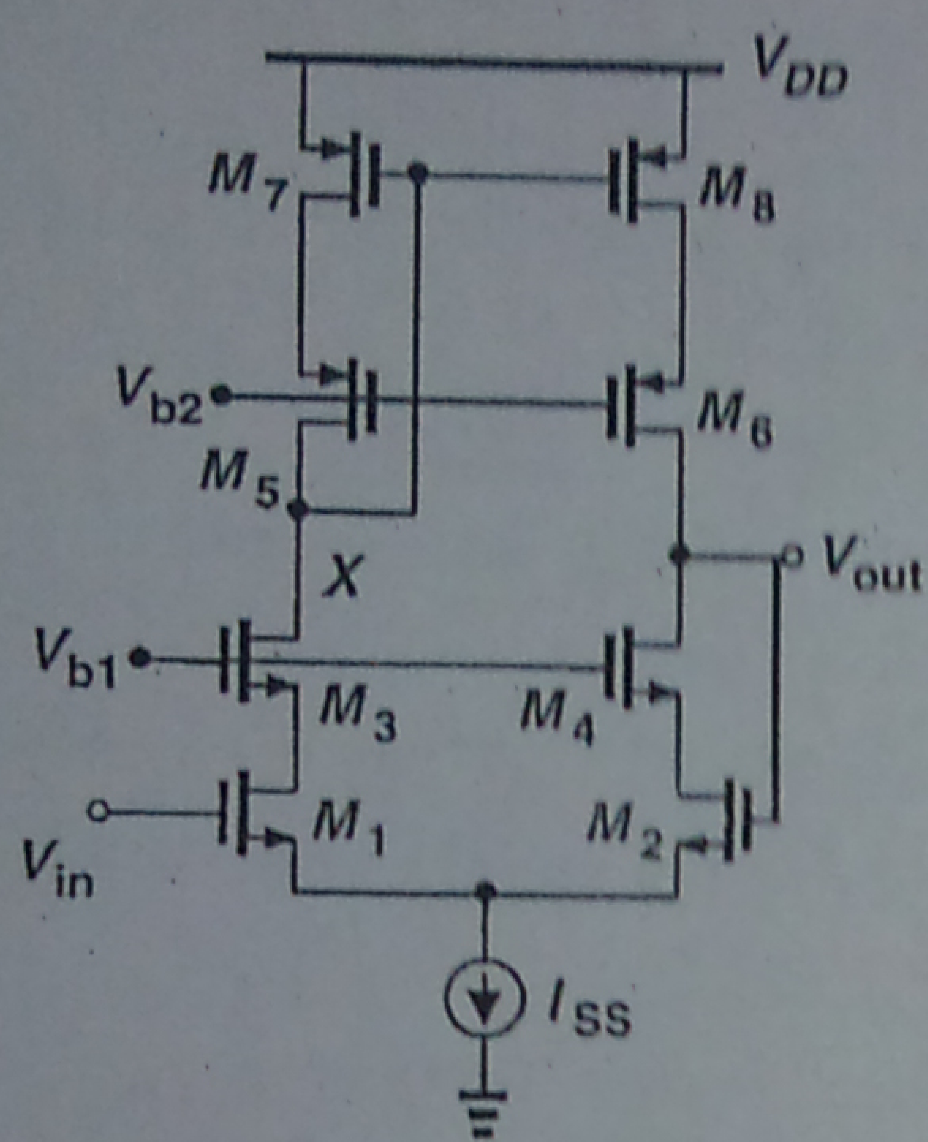


Fig. 13

14. Assume an Op Amp with DC-gain = 80dB, pole1 = 10Mhz, and pole2 = 1000Mhz. (6%)
    (a) Sketch the Bode-Plot (amplitude & phase). (2%)
    (b) Find the unity-gain frequency. (2%)
    (c) Propose a frequency compensation method to get a PM=45°. (2%)

15. Find slew rates of the following Op Amps with $I_{SS} = 1uA$ and $I_1 = 2uA$. (4%)
    (a) Telescopic amplifier with $C_L = 1pF$. (2%)
    (b) 2-stage OP Amp with capacitor $C_C = 0.1pF$. (2%)

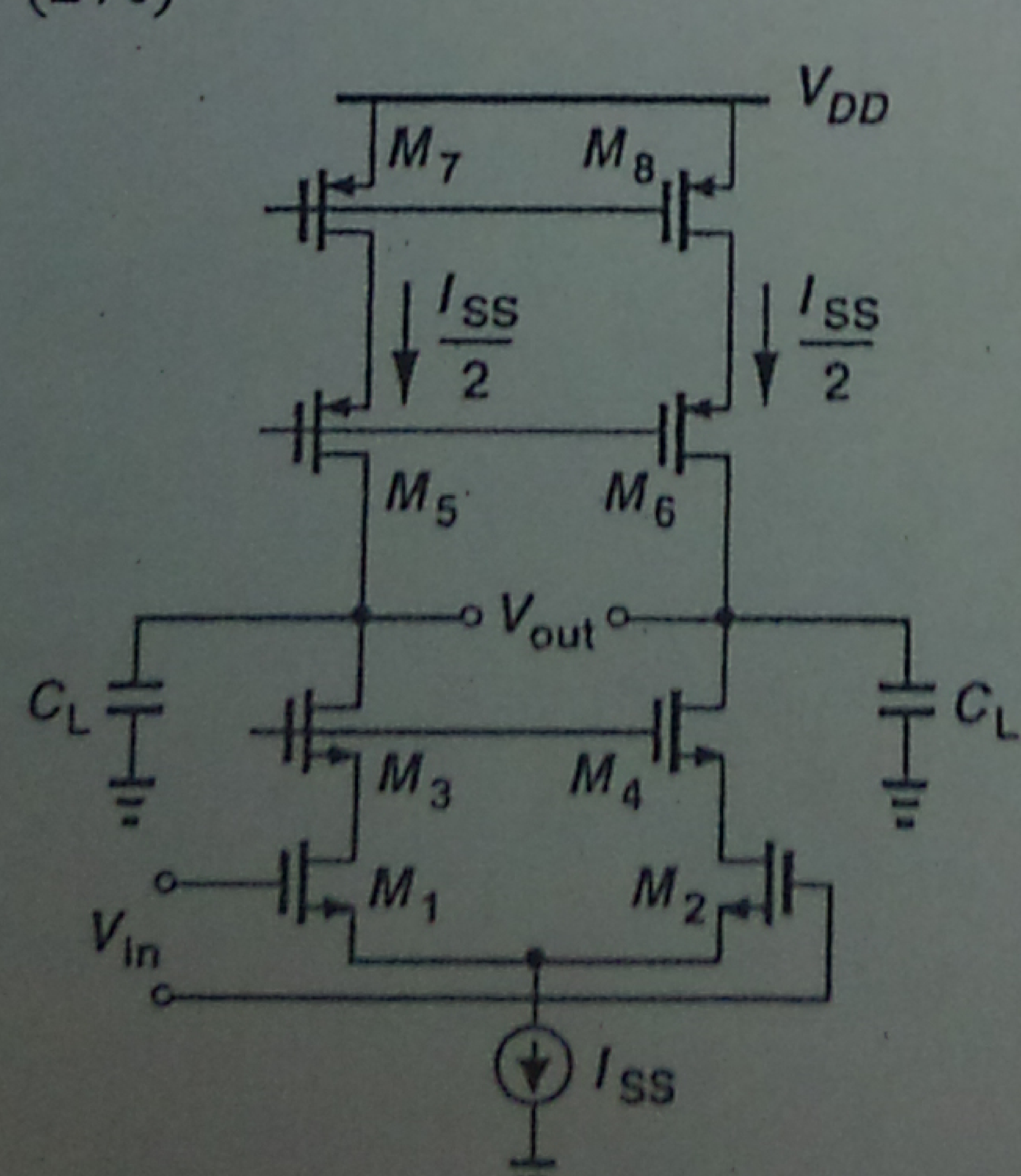


Fig. 15(a)

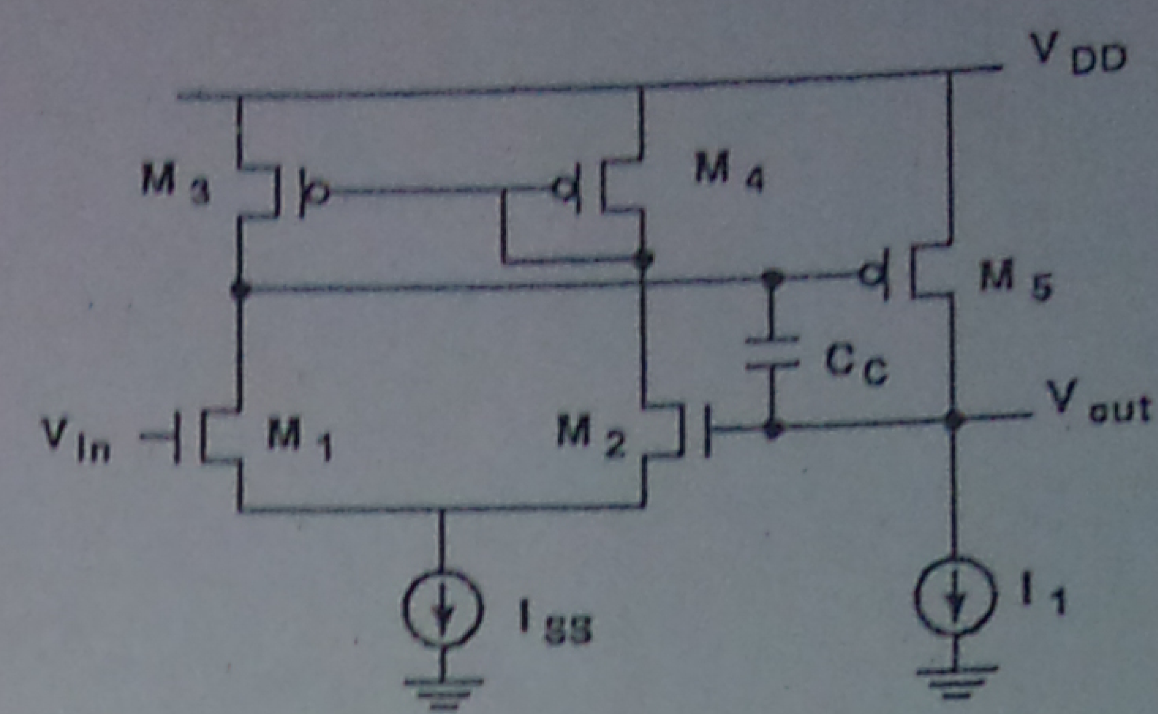


Fig. 15(b)

16. A two-stage Op Amp is shown in Fig. 16 with two low-frequency pole and 0° PM. (4%)
    (a) How to do the frequency compensation by adding Cc. (2%)
    (b) How to solve the right-half-plan zero issue introduced by compensation. (2%)

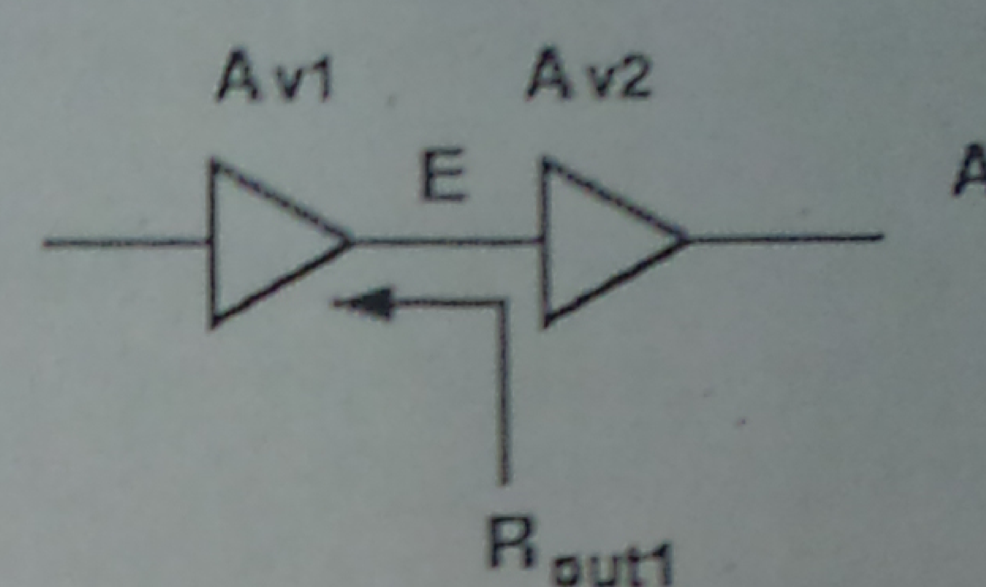


Fig. 16

17. A cascode current mirror as shown in ~~Fig. 12~~, assume all MOSs are biased with $|V_{ov}| = 200mV$, $|V_{th}| = 0.5V$, $I_{REF} = 10uA$, $g_m = 2mA/V$, $r_o = 100k\Omega$, $(W/L)_3/(W/L)_1 = (W/L)_4/(W/L)_2 = 4$, and $V_{DD} = 1.8V$. (4%)
    (a) Find the minimum V_b and related output voltage V_{out} for correct current mirror operation. (2%)
    (b) Find the output resistance R_{out}. (2%)

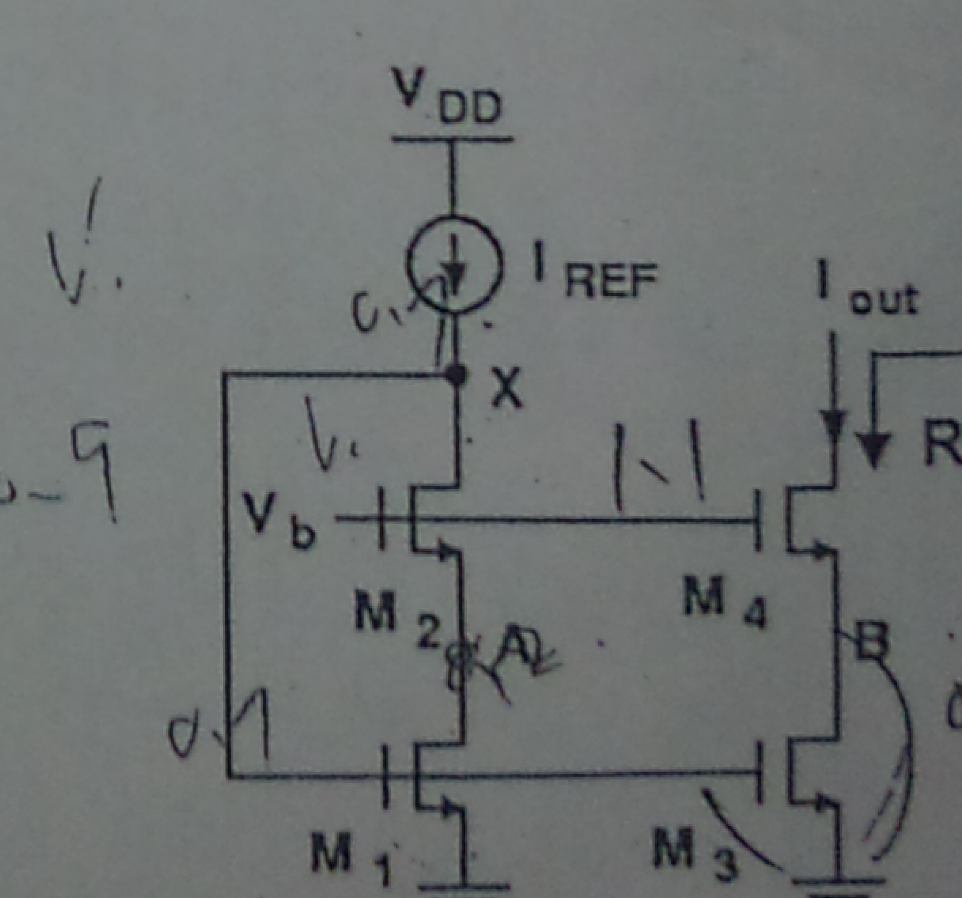


Fig. 12

18. Assume $r_o = \infty$, $g_{mb} \neq 0$ in the circuit of Fig. 19. (4%)
    (a) Sketch the small-signal equivalent circuit. (2%)
    (b) Find the voltage gain V_{out}/V_{in}. (2%)

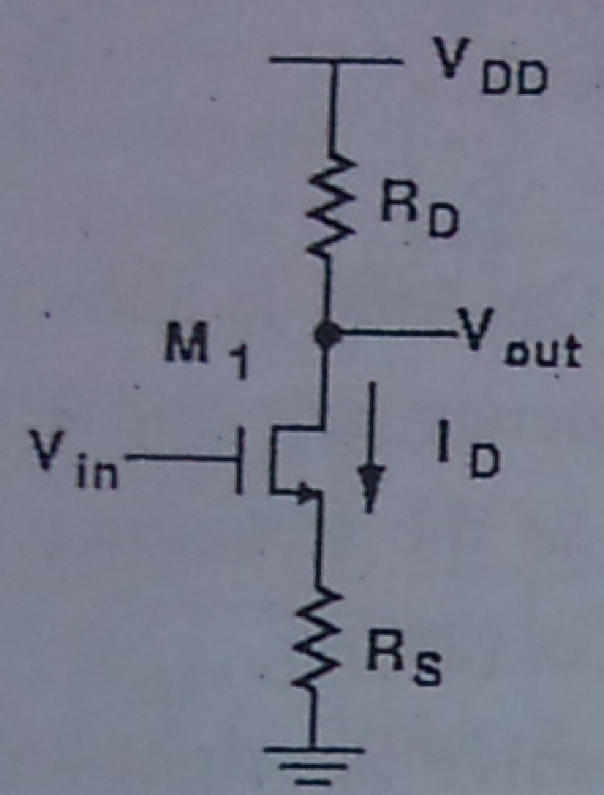
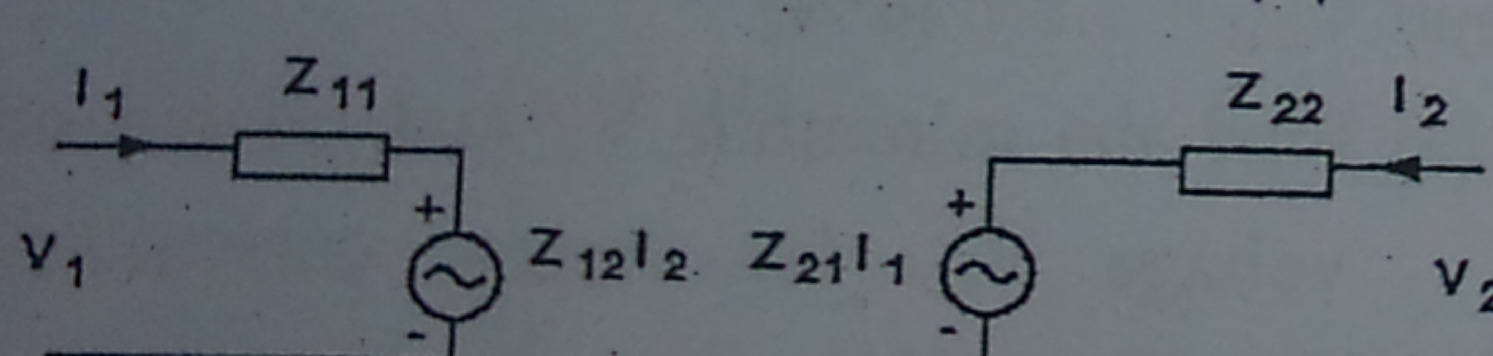


Fig. 19

19. Answer the following questions with TRUE or FALSE: (9%)
    (a) The voltage gain of source follower is independent of body effect. (1%)
    (b) Common gate amplifier is commonly used as current buffer due to its low input impedance. (1%)
    (c) Junction capacitance is proportional to area and reverse-bias. (1%)
    (d) The depletion width of p/n ratio (W_p/W_n) in diode is correlated to doping concentration (N_A/N_D) as $W_p/W_n = N_D/N_A$. (1%)
    (e) Hot carrier effect is due to the high vertical electrical field of channel. (1%)
    (f) The main free carrier in pMOS is hole and from source/drain. (1%)
    (g) The channel charge of MOSFET is proportional to W*L and overdrive voltage V_{ov} as well. (1%)
    (h) The drain current of nMOS at subthreshold region is exponential proportional to applied V_{gs}. (1%)
    (i) For nMOS at saturation region, $C_{GS} > C_{GD}$. (1%)

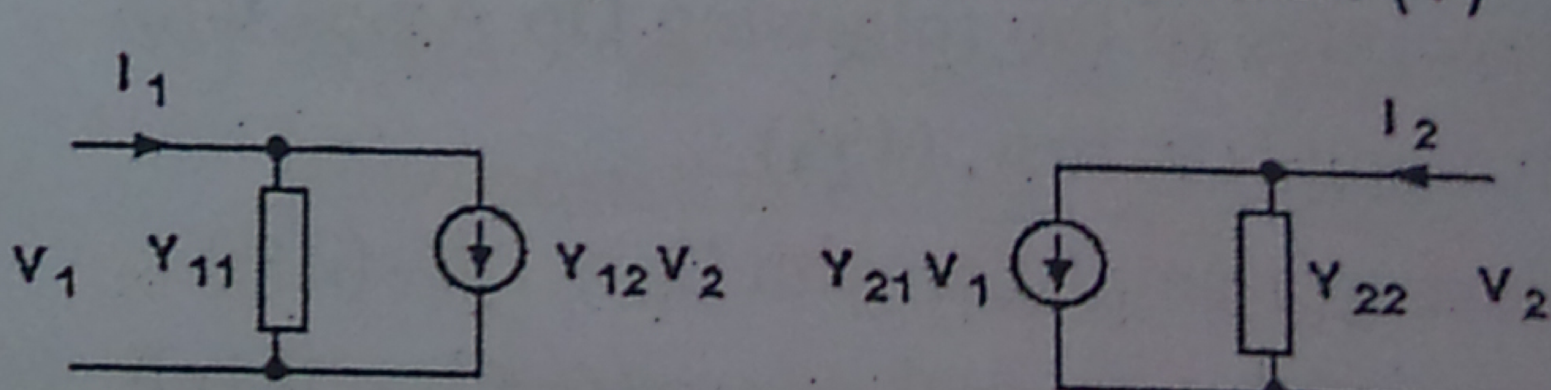
<u>Reference Material</u>

- For current-voltage feedback (Z)



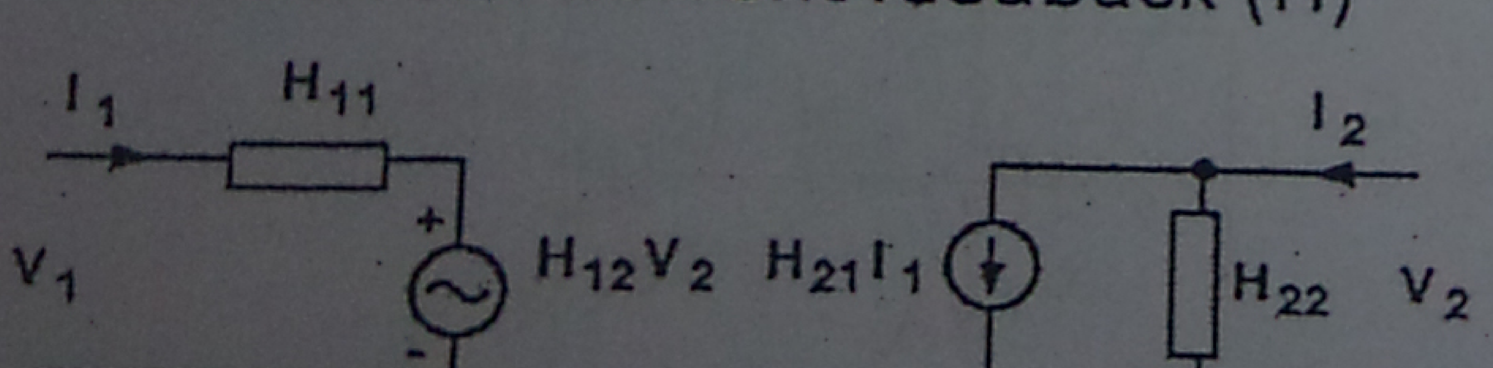
$$V_1 = Z_{11}I_1 + Z_{12}I_2$$
$$V_2 = Z_{21}I_1 + Z_{22}I_2$$

- For voltage-current feedback (Y)



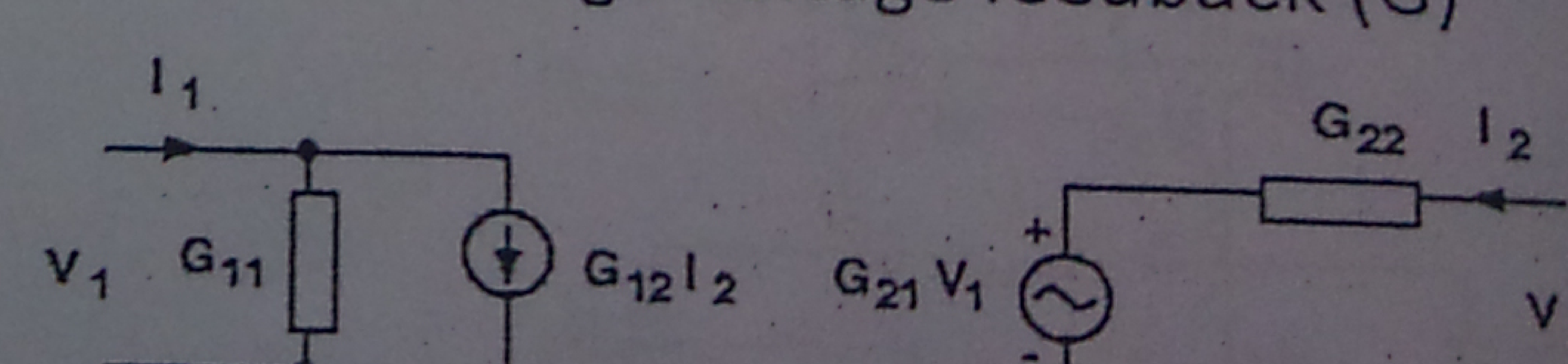
$$I_1 = Y_{11}V_1 + Y_{12}V_2$$
$$I_2 = Y_{21}V_1 + Y_{22}V_2$$

- For current-current feedback (H)



$$V_1 = H_{11}I_1 + H_{12}V_2$$
$$I_2 = H_{21}I_1 + H_{22}V_2$$

- For voltage-voltage feedback (G)



$$I_1 = G_{11}V_1 + G_{12}I_2$$
$$V_2 = G_{21}V_1 + G_{22}I_2$$