1. Consider an imperfect Miller integrator shown in Fig. 1. Let $R = 10\ k\Omega$, $R_F = 1\ M\Omega$, and $C = 10\ nF$. Assume the OP-Amp saturates at ± 15 V.
   (a) Please draw the frequency response of this circuit. Label the dc gain, slope, corner frequency, and unity-gain frequency on the figure to justify your plot. (7 %)
   (b) If $v_I(t)$ is a step function of 0.5-V height starting from $t = 0$, please draw the output waveform $v_O(t)$. Label the time constant and important time/values on the figure to justify your plot. (8 %)

2. Consider the circuit shown in Fig. 2. Assume all diodes have a constant 0.7-V voltage drop when conducting. The Zener diode has the zener voltage of 6.7 V with a negligibly small value of r_z. Please sketch the transfer characteristic (v_O vs. v_I) of the circuit for $-15\ V \le v_I \le +15\ V$. Label clearly the operating condition of each diode on your figure to justify your plot. (10 %)

3. Please draw the characteristics of I_{DS} vs. V_{DS} and I_{DS} vs. V_{GS} of an enhancement-mode n-channel MOSFET under the following situations.
   (a) Increase the gate oxide thickness. (4 %)
   (b) Increase the ambient temperature. (4 %)
   (c) What can you do to "reverse" the situation/trend in (a) and (b)? Explain clearly the condition you plan to apply or adjust and the physics behind it. (7 %)

4. The MOSFET in the amplifier circuit of Fig. 3 has $V_t = 0.6$ V, $k_n = 5\ mA/V^2$, and $V_A = 60$ V. The signal v_{sig} has a zero average.
   (a) What is the value of the drain resistance R_D so that the transistor is operated at an overdrive $V_{OV} = 0.2$ V? You need to consider V_A when calculating the dc drain I_D. (5 %)
   (b) Calculate the values of g_m and r_o at the bias point established in (a). (4 %)
   (c) Find the voltage gain v_o/v_{sig}. (6 %)

5. Design the double-cascode current source shown in Fig. 4 to provide $I = 0.2$ mA and the largest possible signal swing at the output. Assume the transistor has $V_{tp} = -0.4\ V$, $V_A' = -6\ V/\mu m$, $L = 0.4\ \mu m$, and $\mu_p C_{ox} = 100\ \mu A/V^2$ and operate at $|V_{OV}| = 0.2$ V. Specify V_{G1}, V_{G2}, V_{G3}, and the W/L ratios of the transistors. What is the value of R_o achieved? (10 %)

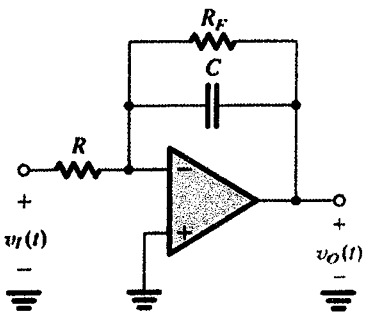

Fig. 1

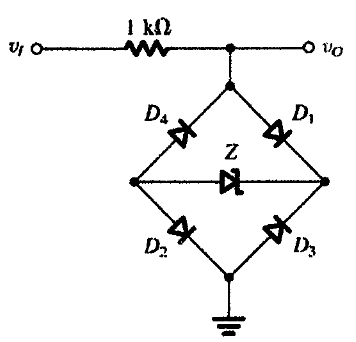

Fig. 2

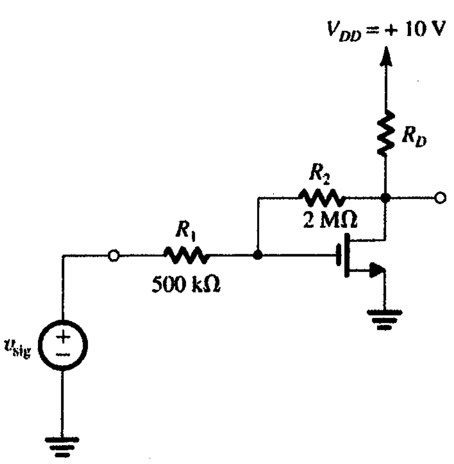

Fig. 3

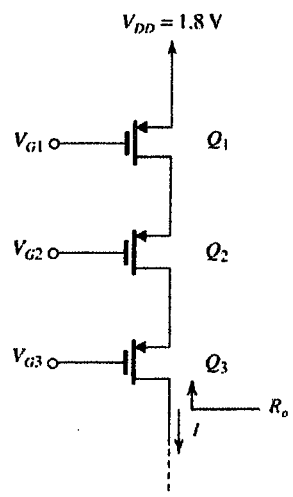

Fig. 4

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6. The circuit of current-mirror-loaded MOS differential pair is shown in Fig. 5. The output can be expressed as an equivalent circuit using $G_m \equiv \frac{i_o}{v_{id}}$ (short-circuit transconductance,), v_{id} (differential input at v_{G1} and v_{G2}), and R_o (output resistance).
   (a) Please derive the expression of G_m and R_o. (10 %)
   (b) Please derive the open-circuit differential voltage gain $A_d \equiv \frac{v_o}{v_{id}}$. (5 %)

7. Sketch a CMOS logic circuit that realizes the function $Y = AB + \bar{A}\bar{B}$. (10 %)

8. Assume the manufacturing technology for 6T SRAM can reduce the bit cell area to 0.04 μm^2. Please estimate the required area of a 1-Gbit memory chip given that the peripheral and I/O circuits will take about 50 % of your memory area. (10 %)

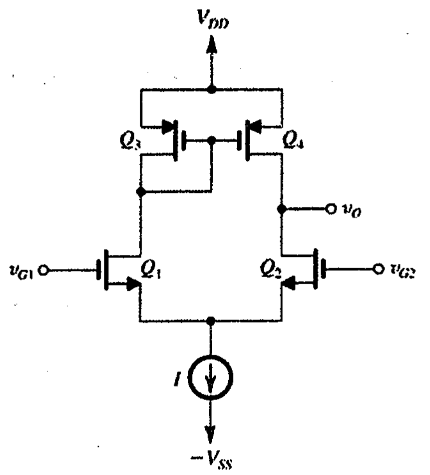

Fig. 5

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